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SPACE RESEARCH INSTITUTE
MONTREAL

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MM 91 – 356, Serial 4MM4-34

U.S. ARMY MATERIEL COMMAND

CANADA

REPORT
of the

MAY/JUNE 1965

TEST FIRING SERIES

PROJECT HARP

SRI-H-R-10

Prepared by:

H.J. LUCKERT

In cooperation with the Staff of the

SPACE RESEARCH INSTITUTE
of
McGill University

and the

FREE FLIGHT AERODYNAMICS BRANCH
BALLISTIC RESEARCH LABORATORIES
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THE PARAGON BUILDING –H.A.R.P.'s HEADQUARTERS ON BARBADOS

ABSTRACT

This report is a review and analysis of results of the eleventh test firing series of Project HARP with the Barbados 16.4 in gun. The test series consisted of twenty rounds which were fired in the period 31 May to 12 June, 1965.

The general objective of this series was the gathering of scientific data, specifically wind shear data, and the continuation of vehicle development and reliability tests.

Eleven rounds carried TMA release payloads for wind shear measurements in synoptic firings during three nights. In three of these rounds a 250 MHz telemetry package was carried with a temperature gauge and a magnetometer for temperature and magnetic field measurements. Modified Martlet 2C vehicles were instrumented with 1750 MHz telemetry and Langmuir probes, as well as with a magnetometer and temperature gauges, for electron density measurements in the upper atmosphere. Ejection tests with S-band chaff and parachute-suspended telemetry were also included in this series, and the structural performance of rocket grain at high launch accelerations was tested in two rounds.

The series was, in general, successful in meeting the set objectives. The mechanical performance of the gun system proved satisfactory, and the ballistic performance with M8M propellant

confirmed previously obtained results. A record apogee of 444,000 ft (135 km) was obtained in one round with a muzzle velocity of approximately 6,100 ft/sec, a vehicle weight of 186 lb, a shot weight of 416 lb, and a breech pressure of 48,000 psi.

The performance of the vehicles proved good. In some cases a large azimuth dispersion was observed which, however, was traced back to a pusher plate and gun barrel problem; appropriate modifications eliminated the dispersion. In two Martlet 3B firings the fins were stripped in the barrel; this could also be attributed to defects in the barrel since, in later firings of these vehicles under the same conditions in another gun barrel, no fin damage occurred.

In all eleven TMA night shots, trails and their photographs were obtained, although cloudy weather conditions made the evaluation of wind data in four of these rounds impossible. The tests with end-burning type rocket grain, manufactured by Lockheed Propulsion Company, were highly successful in that the grain survived accelerations of about 9,000 g's intact and without any change, as shown by X-ray photographs of a recovered motor.

Three test flights with the objective of demonstrating the feasibility of the use of flux-gate magnetometers on HARP vehicles showed that the magnetometers survived the launch and were able to perform during the flight. The 250 MHz telemetry performance, however, was poor, and the causes of the failures need to be explored. Rounds with 1750 MHz telemetry and Langmuir probes, on the other hand,

indicated that the transmitter could survive the high launch accelerations. Good results were obtained from the Langmuir probes; the electron densities obtained agreed well with those expected in the D-layer of the ionosphere.

Ejection tests with the BRL-designed pyrotechnic fuze system were not successful and showed that the system in the present form was not useable.

This report, following the pattern of the report on the previous test series (SRI-H-R-9) contains brief descriptions of the various vehicle configurations and their payloads, as well as detailed performance data of all rounds. This is complemented by an analysis of test results and instrumentation, discussions of ballistic performance of the gun, presentation of tables and graphs of wind shear data obtained in this series, and a compilation of the results of the telemetry experiments.

ACKNOWLEDGMENTS

The work described in this report was carried out as part of the continuing HARP program. As such it has been a joint effort between the staff of the Space Research Institute (SRI) of McGill University and the personnel of the Ballistic Research Laboratories (BRL), Aberdeen Proving Ground.

The assistance of Government agencies and contractors who participated in the program must be acknowledged. In particular, the support from Eglin Air Force Base, Space Instruments Research (SIR), and Lockheed Propulsion Company, is most gratefully acknowledged.

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1.0 INTRODUCTION

This report is a review and analysis of the results of the eleventh test firing series of Project H.A.R.P. with the Barbados 16.4 in. gun. In this series twenty rounds were fired in the period 31 May to 12 June, 1965.

The March test series had clearly demonstrated the capability of the new gun barrel with its 51 ft extension, installed after the December 1964 firing series. The barrel length of approximately 90 calibers had considerably increased the muzzle velocity which could be achieved without exceeding the design limits of the vehicles. Furthermore, it had shown that the Martlet 2 vehicles with balloon and TMA release were substantially operational. Some improvement in balloon release was indicated; the TMA release system, however, worked properly and was considered ready for synoptic firings. Finally the Martlet 3 firings had shown that rockets could be successfully launched at the required accelerations by using fiberglass casings and end-burning grains.

The general purpose of the test series reported here was essentially two-fold:

(1) scientific data gathering, specifically the correlation of wind shear and ionosonde drift data, as well as the data from experimental payloads on the Martlet 2;

(2) a continuation of vehicle development and reliability tests.

The twenty shots of the series were grouped as follows:

(1) Three Martlet 2A firings for ejection tests. Two vehicles were loaded with S-band chaff packages and one vehicle with parachute and telemetry to measure ambient temperatures from 300,000 ft down.

(2) Twelve Martlet 2C firings with TMA release for wind shear data in synoptic firings. Three of these vehicles carried, in addition to the TMA payload, 250 MHz telemetry with a temperature gauge and a magnetometer for temperature and magnetic field measurements. One of the twelve rounds was fired in daylight as vehicle engineering test.

(3) Three Martlet 2C Mod. 1 firings for measurements of electron densities in the upper atmosphere. The vehicles were instrumented with 1750 MHz telemetry and Langmuir probes, magnetometer and temperature gauges.

(4) Two Martlet 3B firings to check rocket structural performance. The airframes provided by S.R.I. were loaded with rocket grains manufactured by Lookheed Propulsion Company.

Table I lists the twenty firings in chronological order.

TABLE I

CHRONOLOGICAL LIST OF FIRINGS - MAY/JUNE 1965 SERIES

Shot No.	Name	Date May/June 65	Time (hr AST)	Vehicle Martlet	Payload	Comments
1	APPIUS	May 31	1347	2A	S-band chaff to be ejected at T + 120 sec.	Successful launch. No evidence of payload ejection.
2	RUFUS	June 2	1515	2A	Parachute with 1750 MHz telemetry and thermistors for ambient temperature measurements. Telemetry broadcasting from launch to monitor the flight.	Successful launch. No evidence of payload ejection.
3	DEVILS	June 3	1432	3B	8 in. solid Lockheed composite grain potted in the case with epoxy.	Launch photographs showed that fins were stripped in barrel. Good launch of case and grain.
4	IRE	June 3	1654	2C(Mod 1)	7 channel BML/GCA 1750 MHz telemetry.	Telemetry data recorded on all channels. Successful flight.
5	MARIUS	June 3	1957	2C	5.5 lb TMA with delay release.	Successful flight. Good TMA trail seen.
6	NERO	June 3	2241	2C	5.5 lb TMA with delay release.	Successful flight, with TMA trail.
7	ELAGABULUS	June 4	0134	2C	5.5 lb TMA with delay release.	Successful. Trail clearly seen for a long time.
8	FABIUS	June 4	0317	2C	5.5 lb TMA with delay release.	Successful. Good trail seen.
9	GRACCHUS	June 5	1100	2C	5.5 lb TMA with delay release.	Successful flight. Daylight shot as vehicle engineering test, not for wind data evaluation.
10	SPARTA	June 5	1322	2A	S-band chaff to be ejected at T + 120 sec.	Good launch. No evidence of chaff ejection.

Shot No.	Name	Date	Time (hr AST)	Vehicle Martlet	Payload	Comments
11	BRUTUS	June 5	1620	2C(Mod 1)	DC Langmuir probe, magnetometer and temperature gauges. Seven channel 1750 MHz telemetry (BML).	Good flight. Telemetry functioned from launch until near apogee.
12	JANUS	June 5	1843	2C(Mod 1)	AC Langmuir probe and magnetometer. A 1750 MHz telemeter was used (BML).	Good flight. Telemetry functioned from launch until T + 210 secs.
13	EAGLE	June 7	1211	3B	8 in. solid Lockheed composite grain and an 8 to 10 second tracer.	Vehicle was launched with fins stripped but otherwise launch was normal. Grain survived the launch.
14	LUCRETIA	June 9	1851	2C	5.5 lb TMA with delay release. 250 MHz telemetry.	Good flight. Magnetometer and temperature gauge functioned. No wind data.
15	OVID	June 9	2157	2C	5.5 lb TMA with delay release.	Good flight and trail.
16	CICERO	June 9	2357	2C	5.5 lb TMA with delay release and 250 MHz telemetry.	Good flight. Telemetry signals weak. Magnetometer and temperature gauge functioned. Good trail.
17	DIANA	June 10	0235	2C	5.5 lb TMA with delay release and 250 MHz telemetry.	Telemetry signals very weak. Magnetometer and temperature gauge functioned. No wind data due to cloud conditions.
18	PLINY	June 11	2107	2C	5.5 lb TMA with delay release.	Successful shot. Good trail coverage.
19	QUINTUS	June 12	0300	2C	5.5 lb TMA with delay release.	Vehicle flew despite pusher plate damage. Due to bad cloud conditions no wind data obtained.
20	HADRIAN	June 12	0431	2C	5.5 lb TMA with delay release.	Successful shot. Good TMA trail coverage.

2.0 FACILITIES AND EQUIPMENT

Facilities and equipment were described in detail in Ref. 1. For this reason only changes from the status of the March series will be mentioned, and a general discussion of the instrumentation added.

2.1 Stations and Equipment

No changes from the conditions of Ref. 1 were made on the gun except for minor modifications. However, for one round (LUCRETIA) the gun was evacuated to test for increased performance. The propellant used for all firings was M8M.220 of the same lot as used in the March series.

Three smear cameras were again operated from the Instrument Hut. The front and side smear were located as in March but the rear smear was moved from a base distance of 240 ft to 250 ft, with a change of elevation above the gun trunnion from 68 ft to 69 ft. The East Fastax and West Fastax stations were also in operation. The East Fastax cameras (10 in. lenses) were focussed at a point 140 ft ahead of the muzzle, and the West Fastax cameras (6 in. lenses) at a point 100 ft ahead of the muzzle. A double smear camera was also used to photograph the vehicle at 150 and 200 ft ahead of the muzzle. All cameras functioned properly during the series

and good results were obtained for the daytime shots. The night shot pictures were underexposed due to insufficient light and could not be interpreted.

The same type of muzzle velocity probe was used as in March, however two additional probes were used; one at a point 5 ft from the muzzle on the left side (looking in shot direction), and another at 6 ft from the muzzle on the right side.

In addition to the S.I.R. tracking stations on Barbados, St. Vincent and Grenada, K-24 camera stations were set up on the island of Tobago which is located southwest of Barbados at a distance of 160 miles. Trails were generated on all flights but the K-24 photographic data were incomplete in some cases because of the poor visibility conditions which prevailed throughout the series.

Trajectory data were furnished by the radar stations for 17 of the rounds; the three exceptions were DEVILS, EAGLE and IRE. On one round (NERO) the MPS-19 radar did not function, and in two rounds (LUCRETIA and PLINY) the velocities were too high for the M-33 radar. The MPS-19 tracks are taken as the primary source of trajectory data but the M-33 results have also been included in the detailed flight performance graphs shown in chapters 3 to 6.

2.2 Discussion of Instrumentation

A great amount of redundant data is collected on each round to allow an estimate of muzzle velocity: Fastax photographs, double smear photographs, muzzle probes. For this series at least it appears as though the Fastax photographs give the most reliable data whereas double smear photographs do not appear nearly as dependable. The muzzle velocity probes tend to be erratic, although their measurements frequently agree very well with other instruments. In general, the results of each type of measurement must be considered and carefully weighed individually for each round in order to decide on a realistic figure of the muzzle velocity.

Some indication of the value of the muzzle velocity is also obtained from supplementary information available on each shot. Breech pressure is one of these measurements since there is a relation between breech pressure and muzzle velocity for a given propellant at standard conditions. In the present series the crusher gauge results, heretofore considered somewhat unreliable, have shown to agree better with other results than the measurements made by the breech pressure gauge which gave about 10 percent smaller results. A possible explanation would be a calibration error.

An estimate of the muzzle velocity could also be derived from radar trajectory data if these data were available

from the time of launch on. Unfortunately this is not the case, as the target can only be acquired several seconds after launch. Although direct apogee measurements are not possible with the two Barbados radars, extrapolation can be expected to yield reliable calculated apogee values which are usually in good agreement with apogee measurements from TMA trails. The muzzle velocity can be determined from the apogee, but only with the assumption of a drag value. Since, however, the exact value of drag in a round is never completely known there is always a certain ambiguity in the computation of initial velocity from the radar data. Within the accuracy of the data one can always make a particular trajectory yield a range of muzzle velocities by making reasonable changes in the drag coefficient. In this report, therefore, the muzzle velocity obtained from the trajectories is for "standard" drag.

3.0 THE MARTLET 2A SERIES

3.1 Vehicle

The Martlet 2A vehicle has performed reliably to altitudes well over 100 kilometers. Schematic drawings of the vehicles with chaff and parachute payloads are shown in Figs. 1a and 1b. Lead ballast was added to the nose to obtain aerodynamic stability.

3.2 Payloads

One payload (Fig. 1a) used in this series was a high altitude S-band chaff designed to be ejected at 120 seconds after launch to determine daytime wind velocities between 300,000 ft and 250,000 ft.

The second payload (Fig. 1b) was a parachute-borne telemetry package to be ejected at T + 120 seconds or about 300,000 ft altitude. The package used five bead thermistors for air temperature measurements.

The ejection system used in the three shots of the 2A series was the BRL designed pyrotechnic fuze system as described in Reference 1.

3.3 Aerodynamics and Predicted Performance

The aerodynamic design provides adequate stability if

the centre of gravity is not less than 22.5 in. from the base. Trajectory estimates for a nominal weight of 180 lb and launch angles of 80 deg, 82.5 deg and 85 deg at a muzzle velocity of 5,000 ft/sec are shown in Fig. 2.

3.4 Firing Program

A total of three Martlet 2A vehicles were fired, two with S-band chaff (APPIUS and SPARTA), and one with the telemetry-parachute package (RUFUS).

All shots were launched successfully and had satisfactory trajectories. Fired with an M8M charge of about 600 lb, they reached altitudes around 80 kilometers. Payload ejection did not occur on any of the flights. The radar tracked all the vehicles to near apogee but did not observe payload ejection. Moreover, in the telemetry round, the telemetry signals continued until splash-down giving additional evidence that the payload was not ejected. It can only be concluded that the ejection mechanism used here is not satisfactory.

The flight results of the three rounds are summarized in Table II, and detailed flight performance of each round is given in Section 3.5.

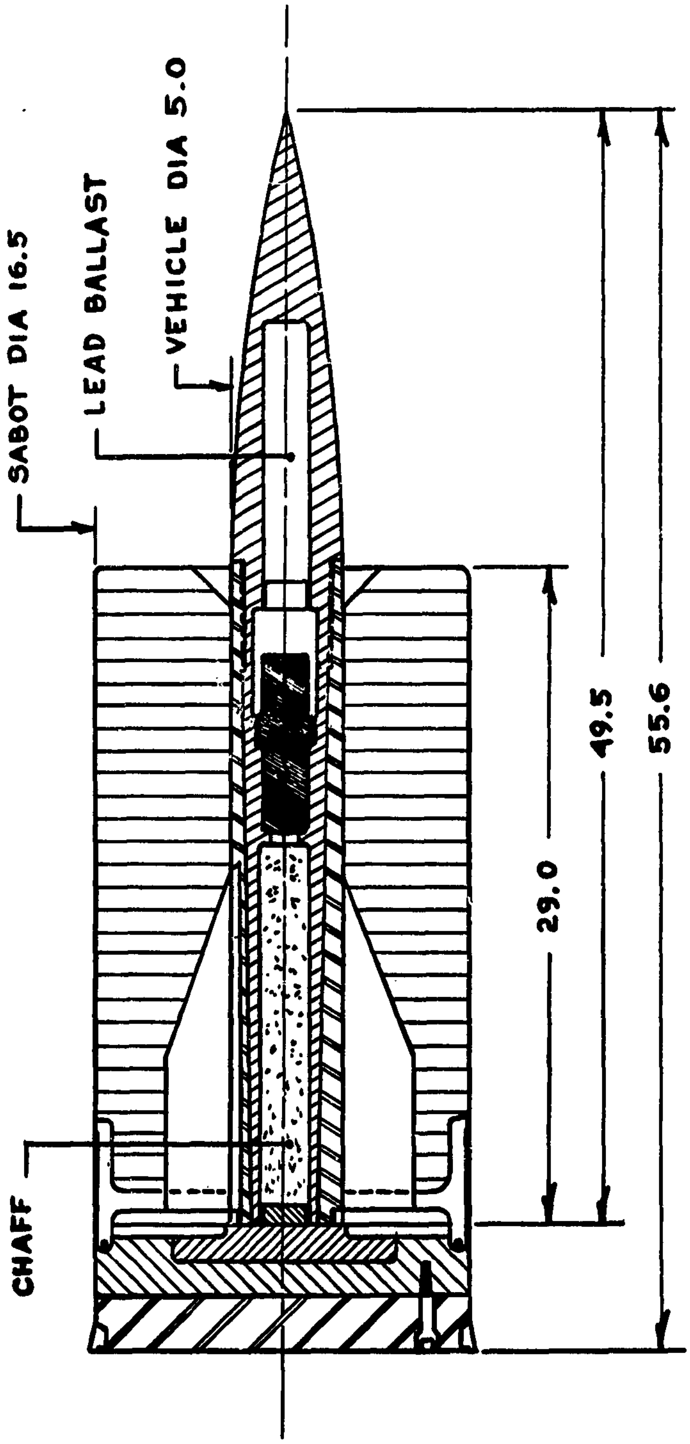


FIG. 1a. MARTLET 2A MOD. 2
CHAFF AND LEAD BALLAST PAYLOAD

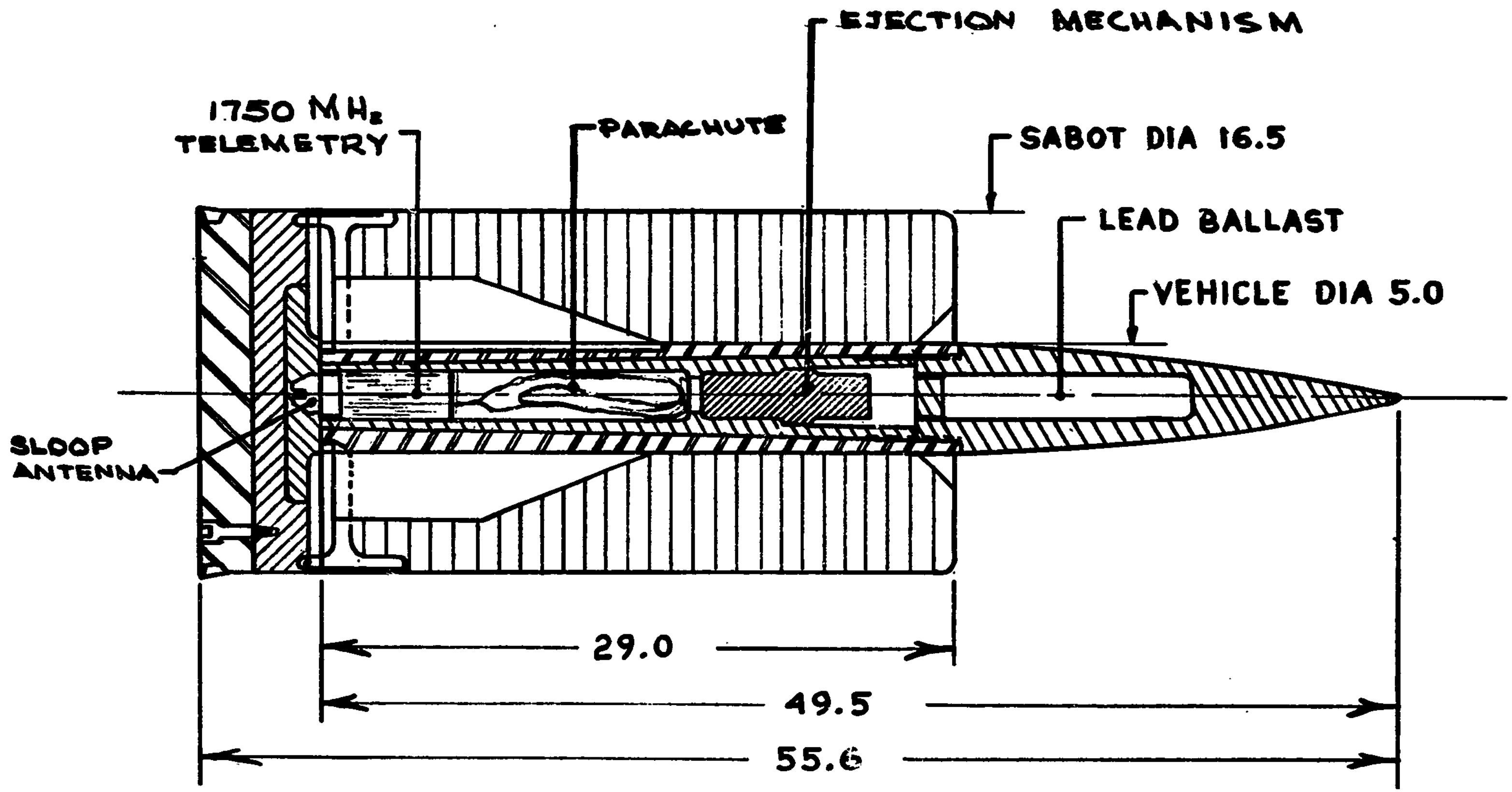


FIG. 1b MARTLET 2A MOD 2
PARACHUTE AND LEAD BALLAST PAYLOAD

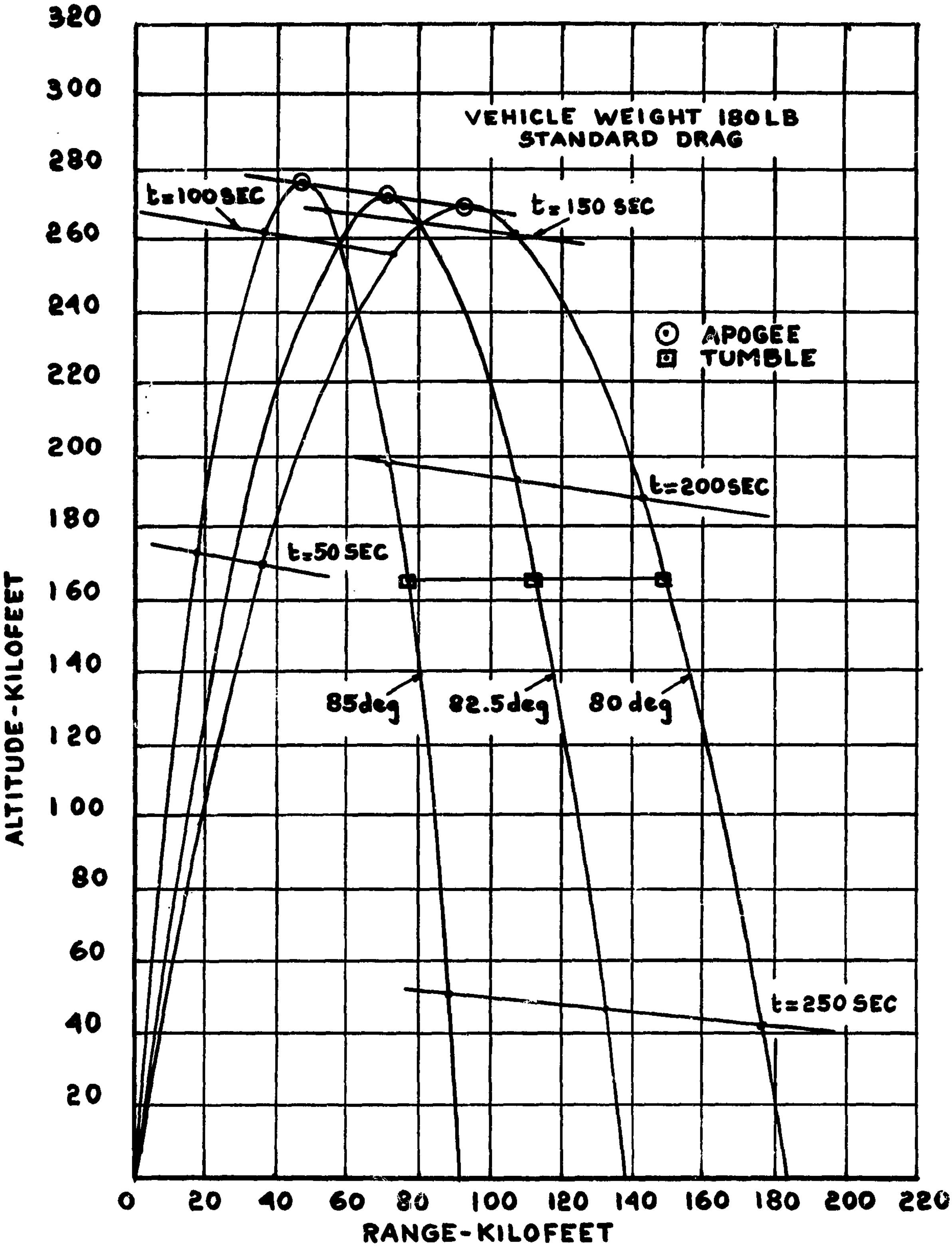


FIG.2 MARTLET 2A TRAJECTORIES
FOR 5000 FT/SEC MUZZLE VELOCITY
WT - 180 LB

TABLE II

MAY/JUNE 1965 - TEST PROGRAM - MARTLET 2A SERIES

FLIGHT	VEHICLE DESCRIPTION	WEIGHT (lb)	LAUNCH DATA	BREECH PRESSURE (psi)	MUZZLE VEL (ft/sec)	APOGEE ft(km)	COMMENTS
1(108) APPIUS 31 May 1965 1347 hr AST QE 85 deg	Martlet 2A carrying a 1.5 lb package of S-band chaff for ejection at T +120 sec.	W_v: 178.0 W_s: 419.8 C : 630 (M8M)	RD: 190.8in RL: 35 tons ChV: 40,530 in^3 Rec: 33.5 in	St: 22,600 Mk6: 24,900 M11: 25,600	P: 5000 5020 5010 R: 5000 WF: 5150 EF: 5120 S: 4760	R: 277,000 (84.4)	Good launch and trajectory. No evidence of payload ejection.
2(109) RUFUS 2 June 1965 1515 hr AST QE 85 deg	Martlet 2A carrying parachute with thermistors (for air temp. measurements) & telemetry. Ejection at T + 120 sec.	W_v: 176.5 W_s: 424.5 C : 585 (M8M)	RD: 188.3 in RL: 100 tons ChV: 40,000 in^3 Rec: 31.5 in	St: 20,500 Mk6: } 21,500 M11: }	P: 4850 4860 4860 R: 4900 WF: 4900 EF: 4870 S: 4550	R: 260,000 (79.4)	Good launch but no payload ejection.
10(117) SPARTA 5 June 1965 1322 hr AST QE 82.5 deg	Martlet 2A carrying a 1.5 lb package of S-band chaff for ejection at T + 120 sec.	W_v: 176.0 W_s: 413.5 C : 600 (M8M)	RD: 192.0 in RL: 25 tons ChV: 40,800 in^3 Rec. 31.3 in	St: 20,500 Mk6: } 20,500 M11: }	P: 4660 4570 4620 R: 4800 WF: 4860	R: 249,000 (76.0)	Good launch and trajectory. No evidence of payload ejection.

W_v = Vehicle Weight
W_s = Shot Weight
C = Charge Weight

RD = Ram Distance
RL = Ram Load
ChV = Chamber Volume
Rec = Recoil

St = Strain Gauge
Mk6, M11 } Crusher Gauges

P = Probe (1st Figure - left, 2nd Figure - right, 3rd Figure - average)
R = Radar
WF = West Fastax
EF = East Fastax
S = Double Smear

3.5 Detailed Flight Performance

3.5.1 Round No. 1 - APPIUS

Date: 31 May, 1965 - 1347 hr A.S.T.

Vehicle Description: Martlet 2A carrying a 1.5 lb package of S-band chaff to be ejected at T + 120 seconds.

Purpose of Test: To check the ejection system and obtain daytime wind measurements between 300,000 ft and 250,000 ft.

Weights:

Vehicle	178.0 lb
Pusher and Obturator	135.5 lb
Sabot	106.3 lb
Shot Weight	419.8 lb

Centre of Gravity: 21 7/8 in. from base

Launch Data:

Charge Weight	630 lb M8M (7 bags)
Swedish Additive	15 sheets
Igniter	500 grams black powder per bag
Gun Elevation	85 degrees
Crusher Gauges	Mk 6 - 2 at 6 tons, - 2 at 8 tons M11 - 4
Ram Distance	190.8 in.
Ram Load	35 tons
Chamber Volume	40,530 in^3
Recoil	35.5 in.
Breech Pressure	Mk 6 24,900 psi M11 25,600 psi Strain 22,600 psi (Fig. 3)
Muzzle Velocity Probe	left 5,000 ft/sec right 5,020 ft/sec average 5,010 ft/sec

Camera Records:

The vehicle launch was recorded satisfactorily on two of three smear cameras.

Fastax cameras and the double smear camera furnished good records; the data gave the following muzzle velocities:

West Fastax (6 in. lens, 160 ft ahead of muzzle) - 5,150 ft/sec

East Fastax (10 in. lens, 140 ft ahead of muzzle) - 5,120 ft/sec

Double Smear (150 and 200 ft ahead of muzzle) - 4,760 ft/sec

The Fastax results are two to three percent higher than the muzzle velocity probe data, whereas the double smear result is five percent lower.

Radar Records:

Using manual tracking the M-33 radar followed the vehicle from T + 15 sec to approximately T + 50 sec. At this time the radar lost the target, and the vehicle could not be acquired again except for a few periods on its way down. No chaff ejection was observed at T + 120 sec, nor was any evidence of chaff found during a search conducted for a total of 45 minutes.

The MPS-19 radar was on the target from T + 4 sec to T + 110 sec very near to apogee. No chaff ejection was observed.

Trajectory:

In Figs. 3a,b,c, the MPS-19 radar data (see Appendix A) are compared with theoretical curves. Fig. 3a shows altitude vs time. Theoretical curves are drawn for an 85 deg gun elevation and for muzzle velocities of 5,000, 5,100, and 5,200 ft/sec. The radar results are in good agreement with the 5,000 ft/sec curve. Fig. 3b shows horizontal range vs time, and indicates agreement with the curve for a slightly higher muzzle velocity.

However, if a small reduction of 0.1 deg in effective elevation angle is assumed, agreement for both altitude and range data is obtained. This assumption is reasonable since altitude is relatively insensitive to small changes of elevation angle. The trajectory does not give any information on which of the measured muzzle velocity values (muzzle probe or Fastax) is correct. As discussed in Section 2.2 and shown in Fig. 3c, the standard drag trajectory for 5,000 ft/sec muzzle velocity and an increased drag trajectory for 5,100 ft/sec are approximately the same. Charge weight and breech pressure data of this round however seem to indicate that the Fastax result is more realistic. This would mean an increased drag coefficient in this flight.

In Fig. 3d, the plan view of the trajectory is shown. A slight deviation in azimuth is noticeable.

The apogee is found to be 277,000 ft (52.5 miles or 84.4 km). This value is obtained by extrapolation of the trajectory taking into account the altitude data above the sensible atmosphere where drag can be neglected.

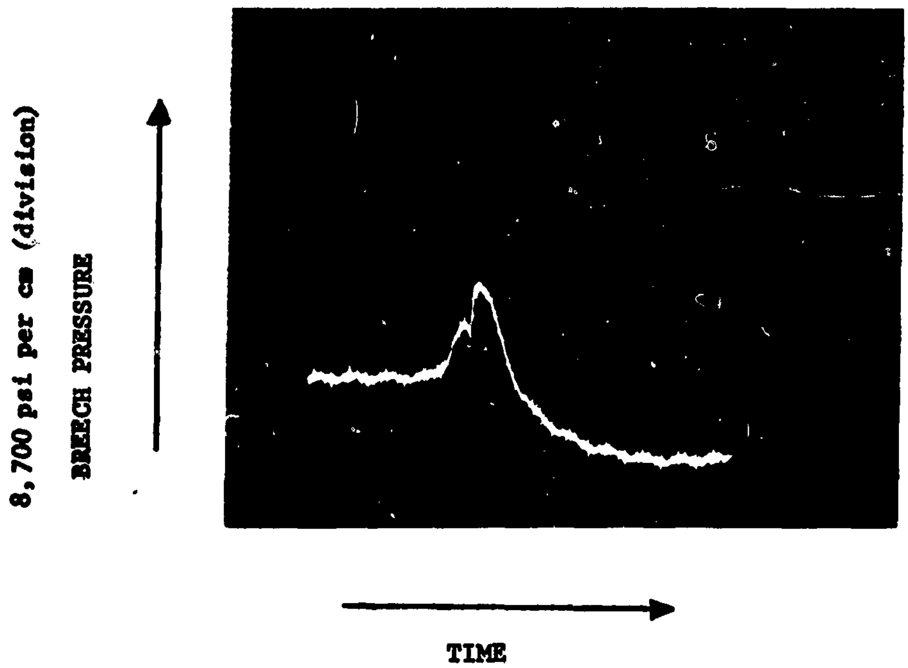
No impact range measurement is available. The estimated value is approximately 93,000 ft.

<u>Summary</u>:

The shot was successful with respect to vehicle performance but unsuccessful in payload performance since apparently no payload was ejected.

APPIUS

31 MAY 1965 - 1347 HR AST



20 milliseconds per cm (division)

Gauge No. AR #6

Maximum Breech Pressure: Pmax = 22,600 psi

Note: Base line shift is due to lack of heat protection for the gauge. (corrected in subsequent rounds.)

Fig. 3 STRAIN GAUGE RECORD OF BREECH PRESSURE ROUND APPIUS

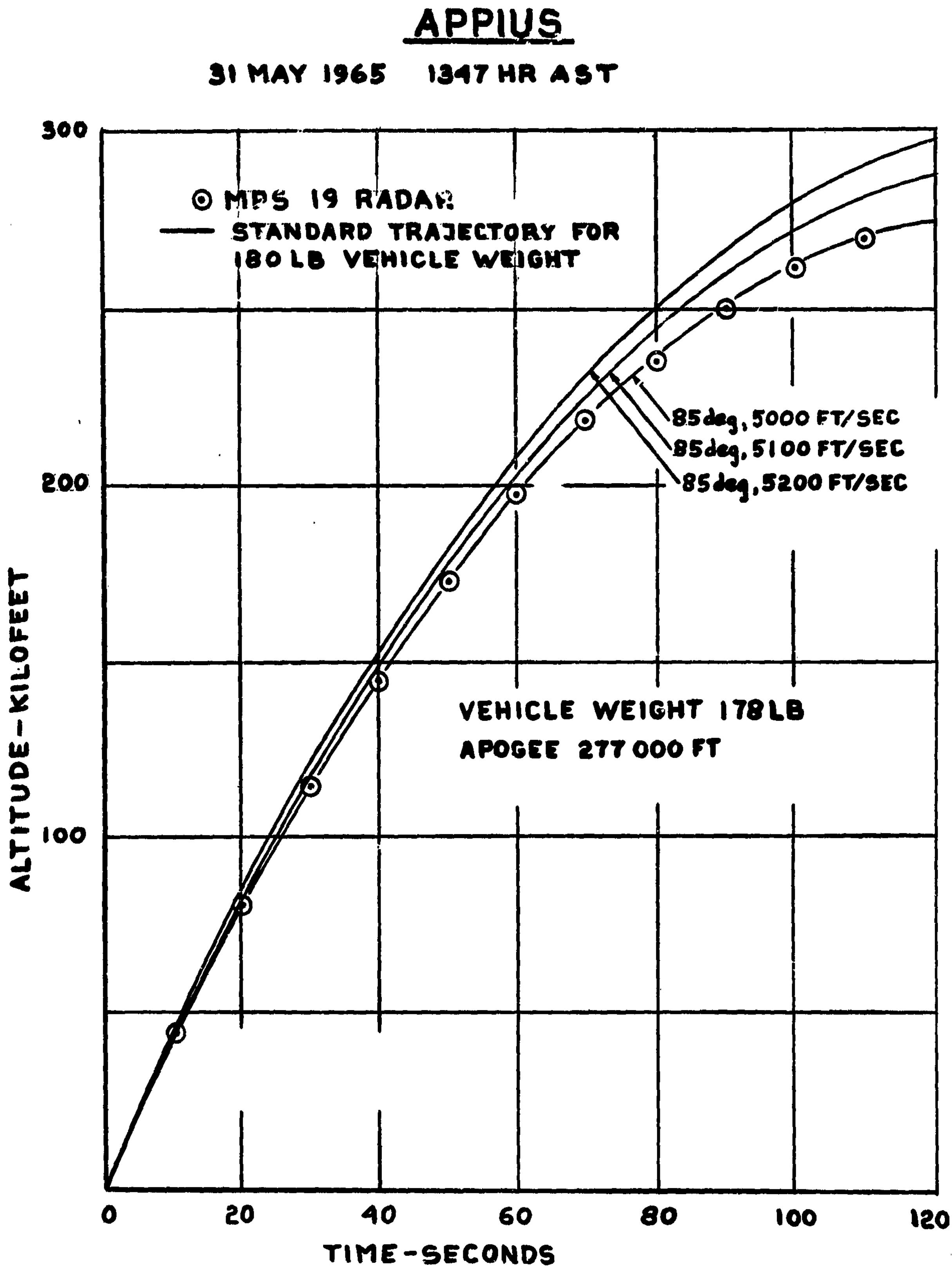


FIG. 3a MARTLET 2A SHOT - APPIUS

ALTITUDE VS TIME

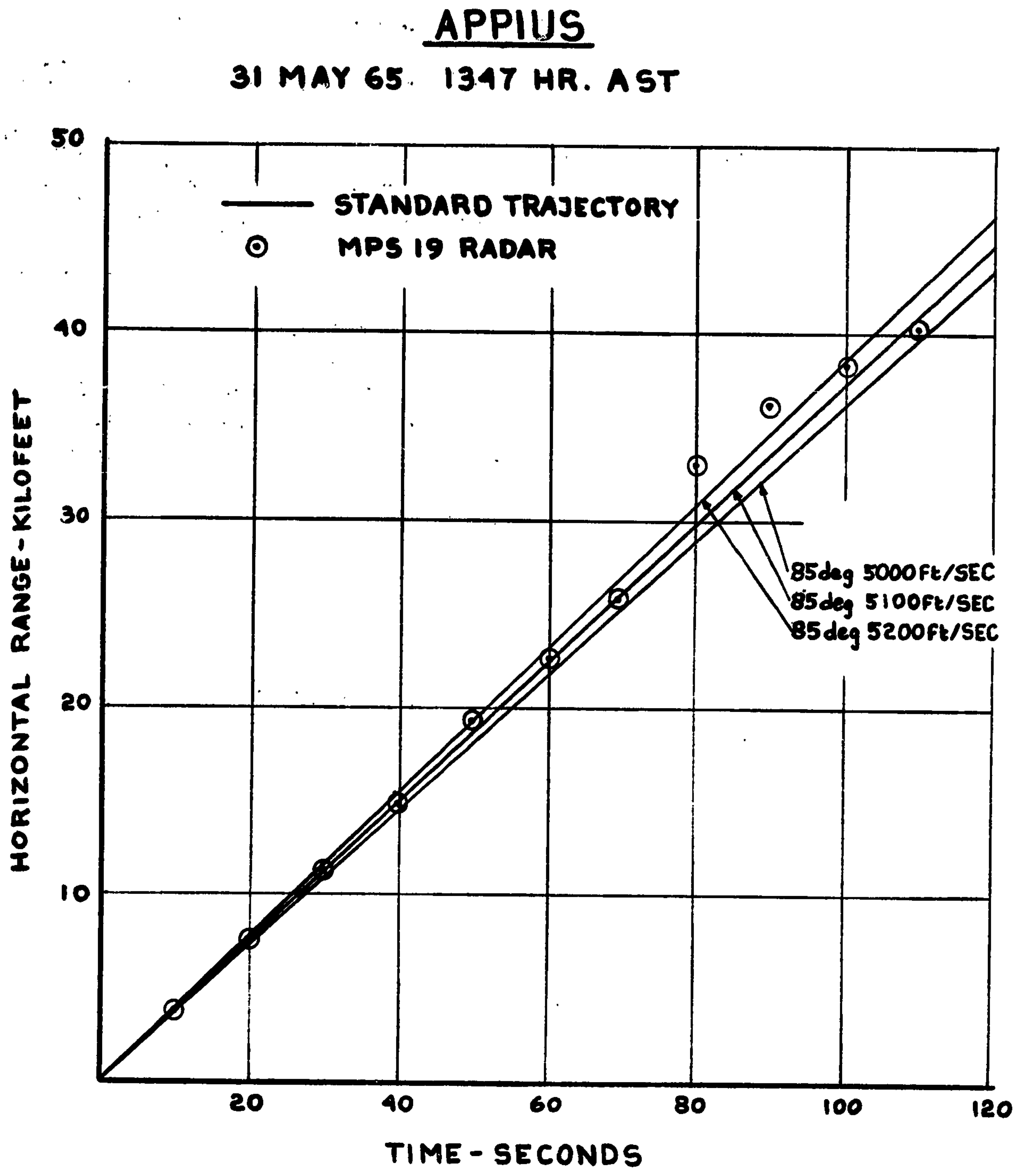


FIG.3b MARTLET 2A SHOT APPIUS

RANGE VS TIME

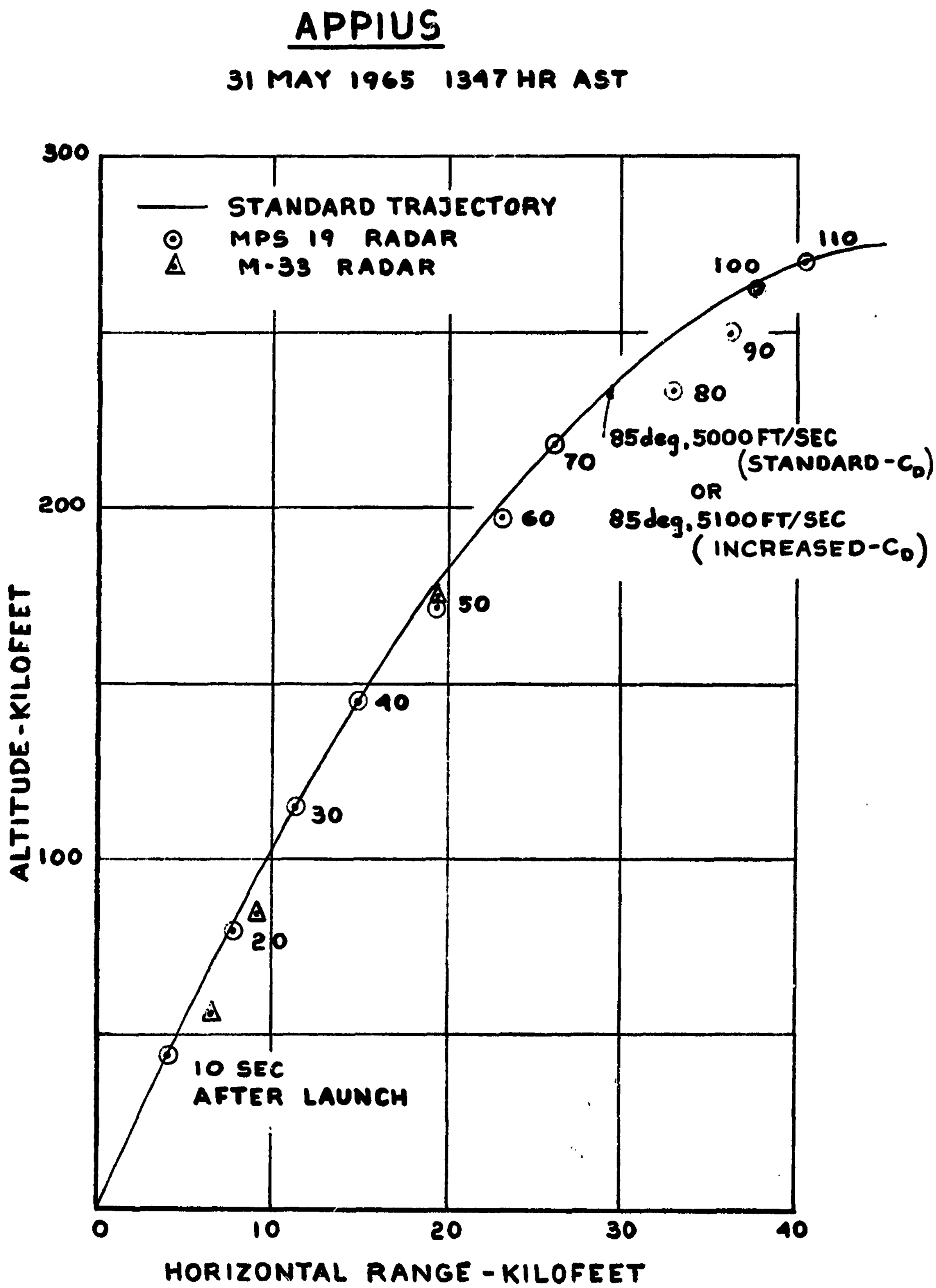


FIG 3c MARTLET 2A APPIUS
ALTITUDE VS RANGE

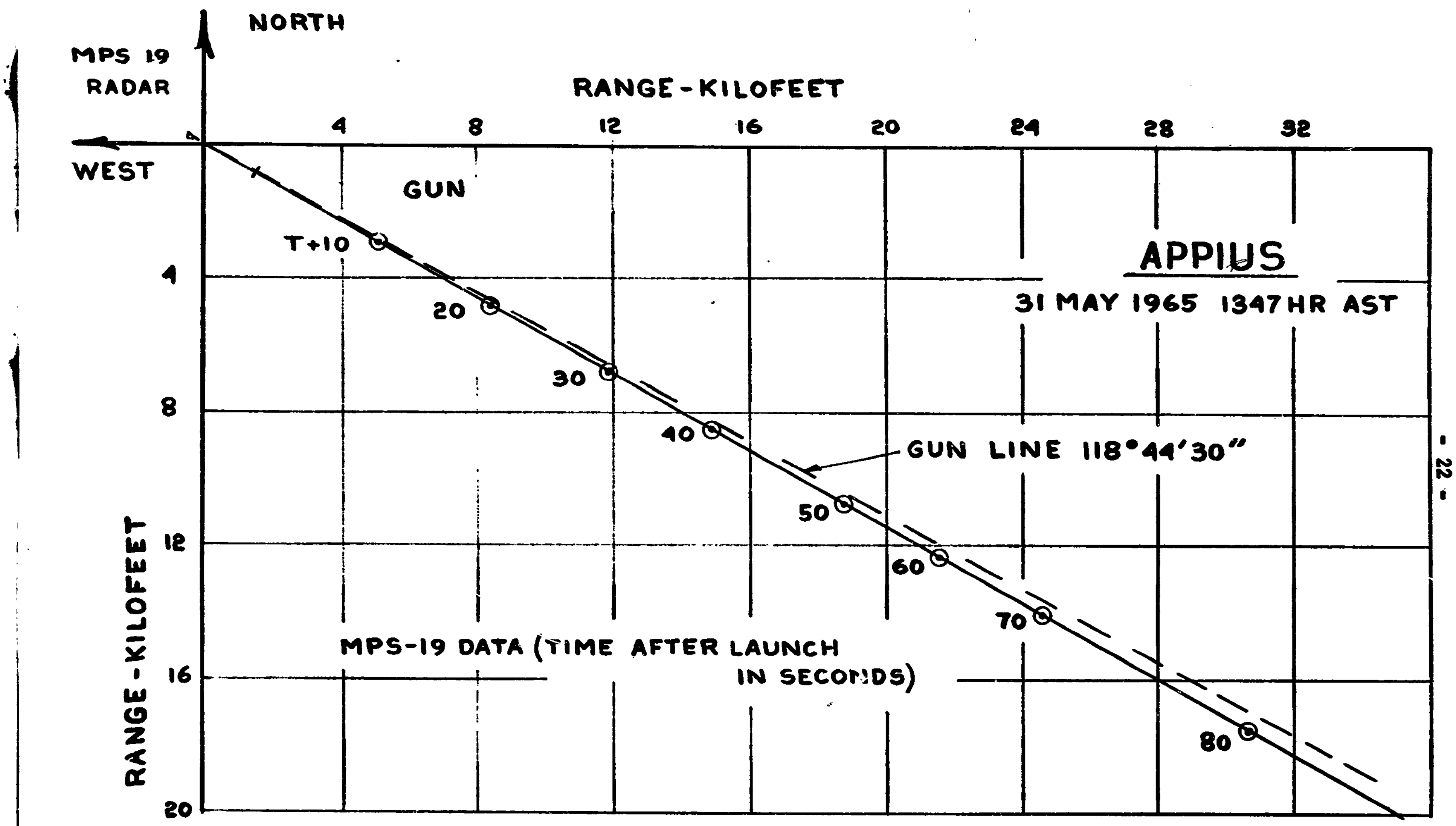


FIG. 3d PLAN VIEW OF MARTLET 2A-APPIUS TRAJECTORY

3.5.2 Round No. 2 - RUFUS

Date: 2 June, 1965 - 1515 hr A.S.T.

Vehicle Description: Martlet 2A carrying parachute with thermistor for ambient temperature measurements below 300,000 ft. Package planned for ejection at T + 120 seconds. 1750 MHz telemetry broadcasting from launch was used to monitor the flight.

Purpose of Test: To check out parachute ejection system and to obtain air temperature measurements between 300,000 and 250,000 ft.

Weights:	Vehicle	176.5 lb
	Pusher and Obturator	145.0 lb
	Sabot	103.0 lb
	Shot Weight	424.5 lb

Centre of Gravity: 21.6 in. from base

Launch Data:

Charge Weight	585 lb M8M (6 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	85 degrees
Crusher Gauges	Mk 6 - 4 M11 - 4
Ram Distance	188 in.
Ram Load	40 tons
Chamber Volume	40,000 in^3
Recoil	31.5 in.
Breech Pressure	Mk 6, M11 } 21,500 psi (average) Strain 20,500 psi (Fig. 4)
Muzzle Velocity Probe	left 4,850 ft/sec right 4,860 ft/sec

Camera Records:

All Fastax and double smear records were good. The evaluation of photographs gave the following muzzle velocity values:

West Fastax (6 in.lens, 160 ft ahead of muzzle) - 4,900 ft/sec

East Fastax (10 in.lens, 140 ft ahead of muzzle)- 4,870 ft/sec

Smear (150 and 200 ft ahead of muzzle) - 4,550 ft/sec.

Radar Records:

The M-33 radar followed the vehicle by manual tracking from 20 seconds to about 60 seconds. The vehicle appeared to wobble. Payload ejection was not seen, nor was the parachute detected.

The MPS-19 acquired the vehicle at T + 4 seconds and tracked to near apogee.

Trajectory:

Fig. 4a to 4d show the radar data compared with the computer curve for 4,900 ft/sec and standard drag. The agreement is acceptable; the range data, though, seem to indicate an effective launch angle of 84.5 deg (Fig. 4b and 4c). The plan view (Fig. 4d) shows that the trajectory is in the vertical plane of the gun azimuth.

The apogee was found to be 260,000 ft which is also in agreement with a standard trajectory for 84.5 deg elevation angle and 4,900 ft/sec muzzle velocity. Note that this is the velocity determined from the FASTAX records.

No impact range measurement is available. The theoretical impact range is 96,000 ft.

Telemetry:

Telemetry functioned from launch to splash with a sharp change of approximately 8 MHz in frequency at T + 100 seconds

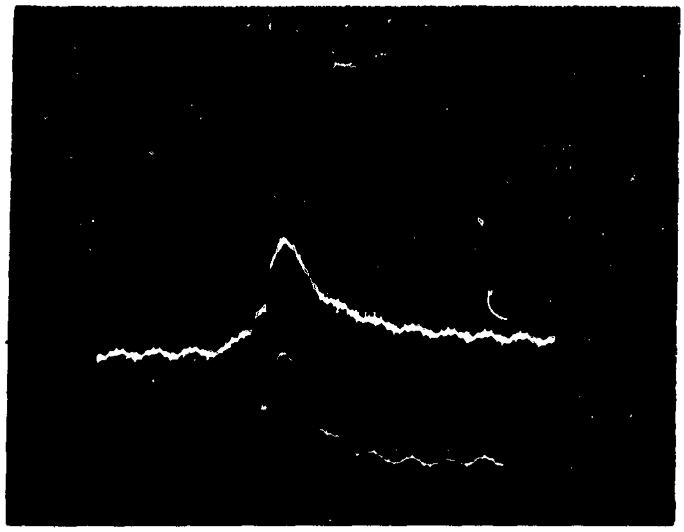
presumably indicating that the fuze fired early. The signal was received from the vehicle position until splash-down at T + 280 seconds. This indicated that the payload had not been ejected from the vehicle.

Summary:

The flight was successful as far as vehicle performance was concerned. All evidence, however, suggested that the payload was not ejected.

<u>**RUFUS**</u>

2 JUNE 1965 - 1515 HR AST



8,700 psi per cm (division)

BREECH PRESSURE

TIME

20 milliseconds per cm (division)

Maximum Breech Pressure: Pmax = 20,000 psi

Fig. 4 STRAIN GAUGE RECORD OF BREECH PRESSURE ROUND RUFUS

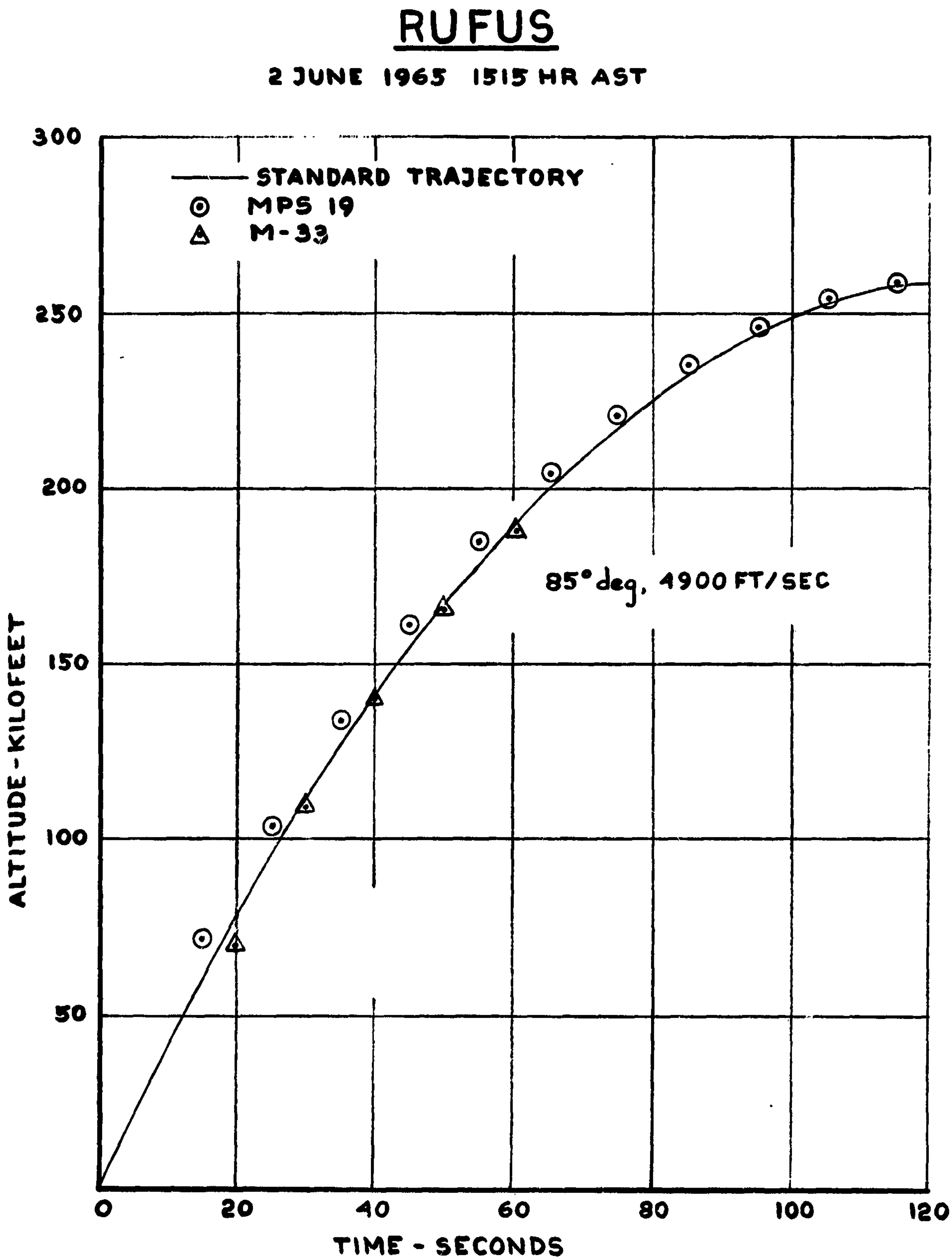


FIG. 4a MARTLET 2A SHOT-RUFUS
ALTITUDE VS TIME

RUFUS

2 JUNE, 1965 1515 HR AST

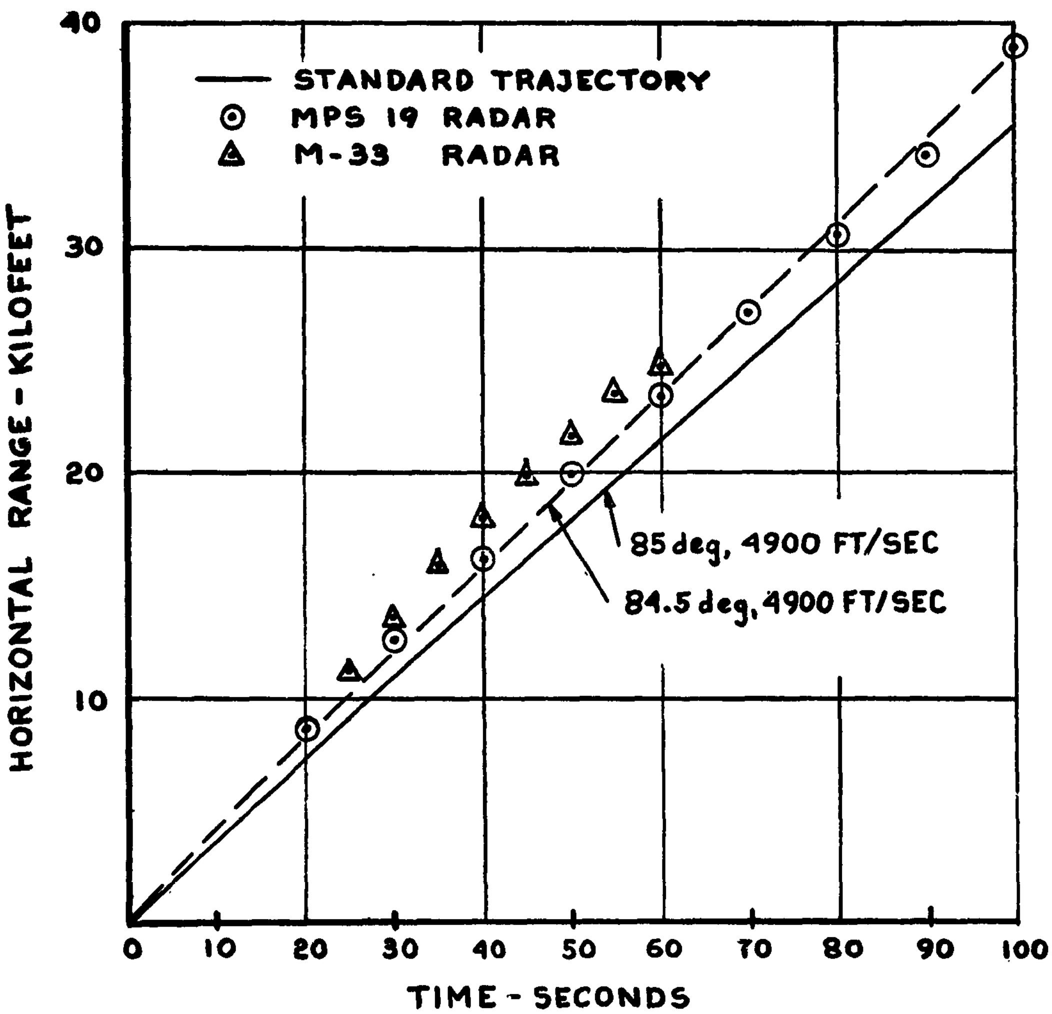


FIG.4b MARTLET 2A SHOT-RUFUS

RANGE VS TIME

ALTITUDE-KILOFEET

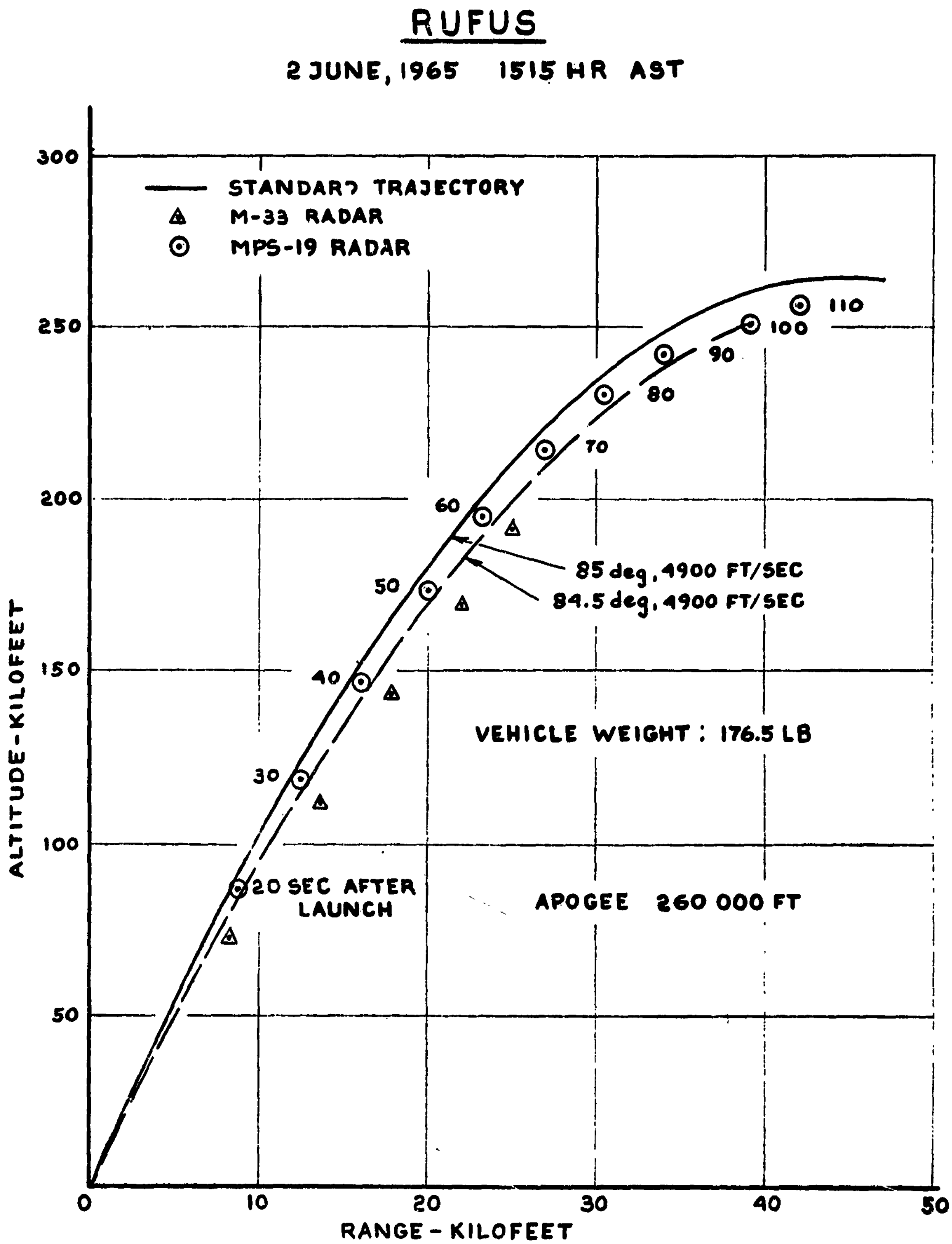


FIG. 4c MARTLET 2A SHOT - RUFUS
ALTITUDE VS RANGE

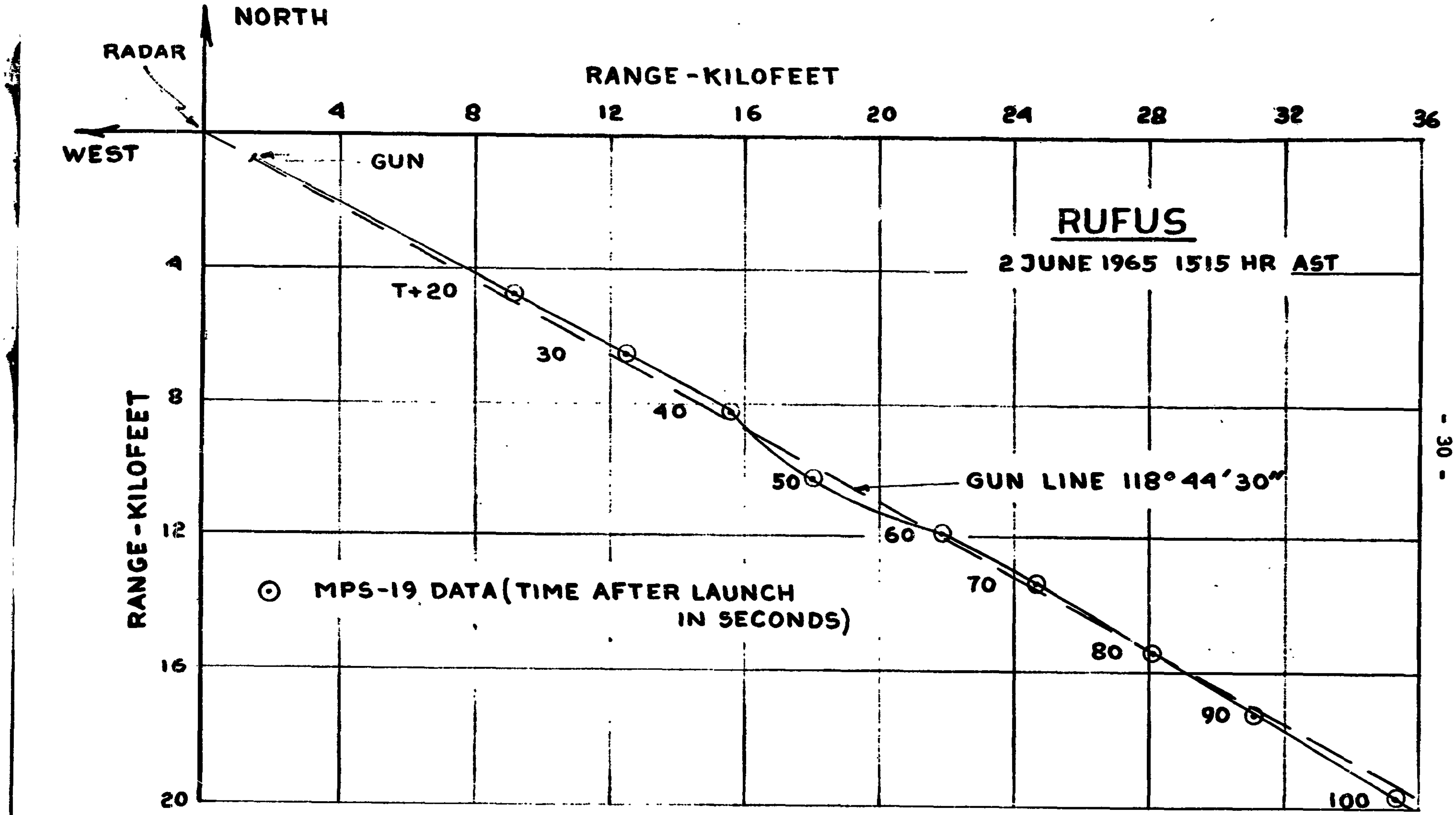


FIG. 4d PLAN VIEW OF MARTET 2A -RUFUS TRAJECTORY

3.5.3 Round No. 10 - SPARTA

Date: 5 June, 1965 - 1322 hr A.S.T.

Vehicle Description: Martlet 2A carrying an S-band chaff package to be ejected at T + 120 seconds.

Purpose of Test: To obtain data on daytime winds between 300,000 ft and 250,000 ft.

Weights:	Vehicle	176.0 lb
	Pusher and Obturator	132.5 lb
	Sabot	105.0 lb
	Shot Weight	413.5 lb

Centre of Gravity: 21.8 in. from base

Launch Data:

Charge Weight	600 lb M8M (6 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	82.5 degrees
Crusher Gauges	M11 - 4
Ram Distance	192 in
Ram Load	25 tons
Chamber Volume	40,800 in^3
Recoil	31 in
Breech Pressure	M11 20,500 psi
	Strain 20,500 psi (Fig. 5)
Muzzle Velocity Probe	left 4,660 ft/sec
	right 4,570 ft/sec

Camera Records:

Good records of launch were obtained on all smear and Fastax cameras. The West Fastax (6 in. lens) photograph indicated a muzzle velocity of 4,860 ft/sec at a distance of 160 ft ahead of the muzzle.

Radar Records:

Both radar stations tracked to near apogee. No payload ejection could be seen. The radar data are given in Appendix A.

<u>Trajectory</u>:

The radar results from both stations are in good agreement with a standard trajectory for 82.5 deg launch elevation and a muzzle velocity of 4,800 ft/sec, as shown in Figs. 5a to 5c. Fig. 5d (plan view of trajectory) indicates that the vehicle in general followed the gun line, with some irregularities after T + 60 secs.

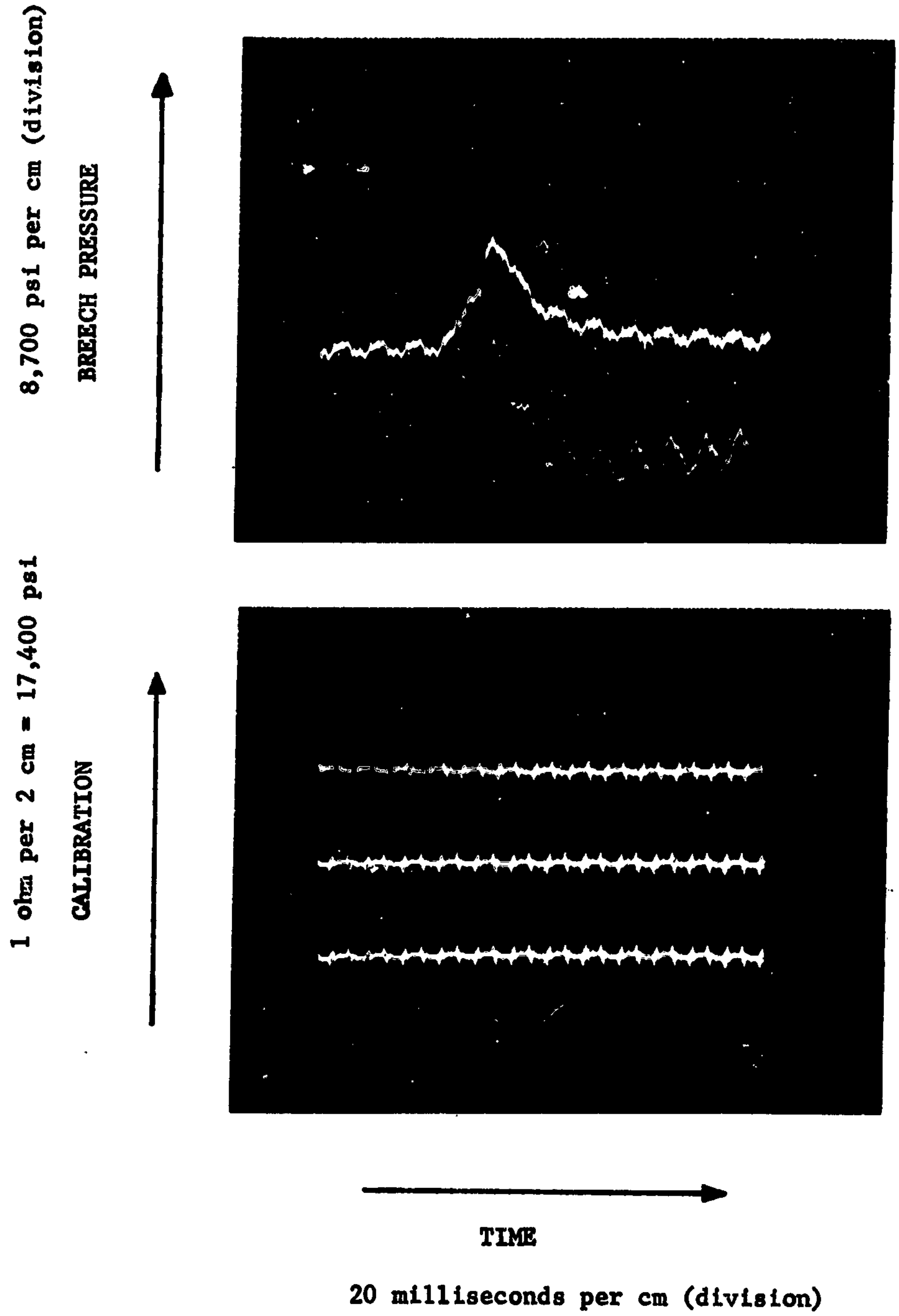
The apogee was 249,000 ft and the estimated range 125,000 ft.

<u>Summary</u>:

Successful launch and good vehicle trajectory; however, there was no evidence of payload ejection.

SPARTA

5 JUNE 1965- 1322 HR AST



Maximum Breech Pressure: P_{max} = 20,500 psi

Fig. 5 STRAIN GAUGE RECORD OF BREECH PRESSURE ROUND SPARTA

SPARTA

JUNE 5 1965 1322 HR AST

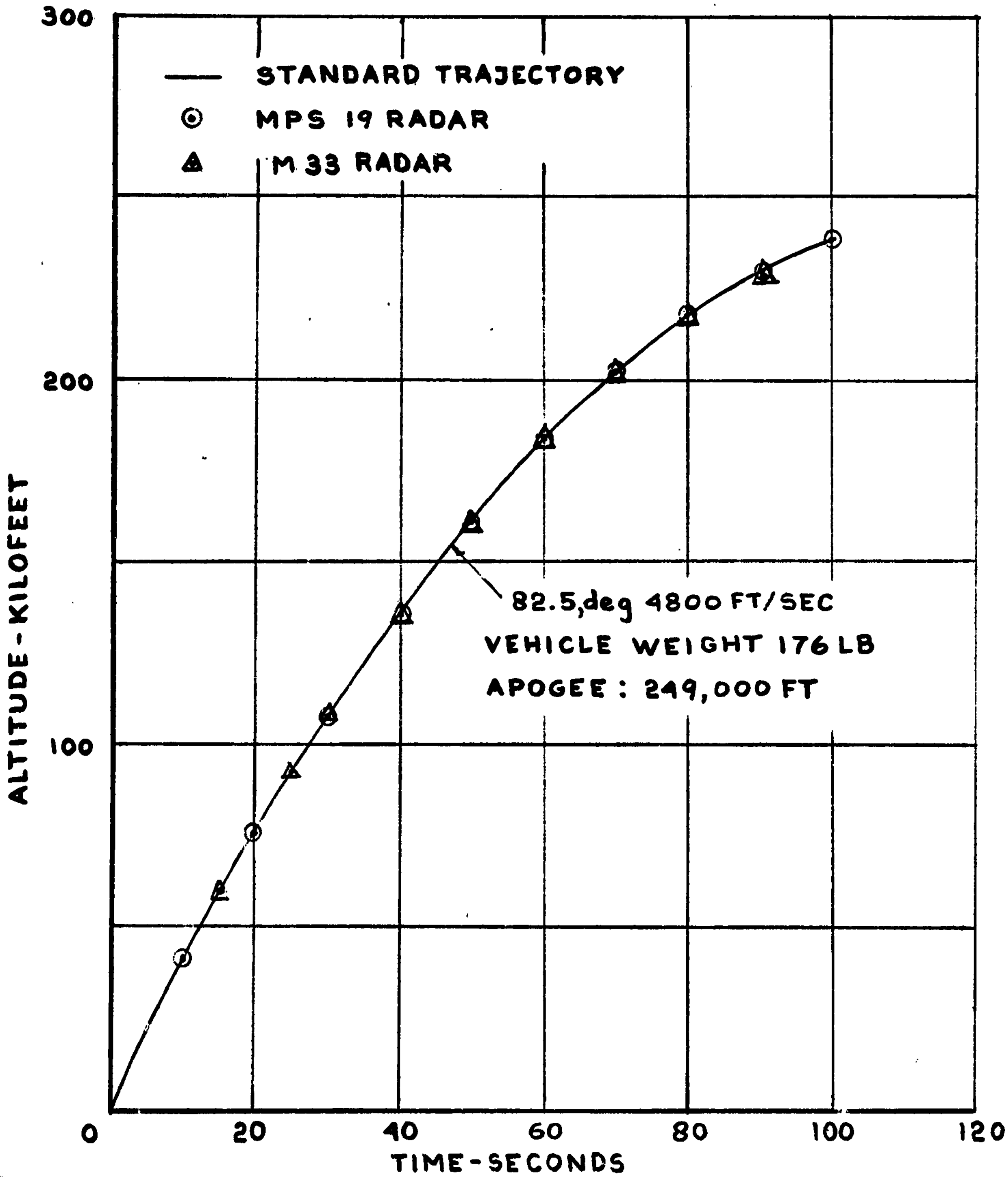


FIG. 5a MARTLET 2A SHOT SPARTA
ALTITUDE VS TIME

SPARTA

5 JUNE 1965 1322 HR AST

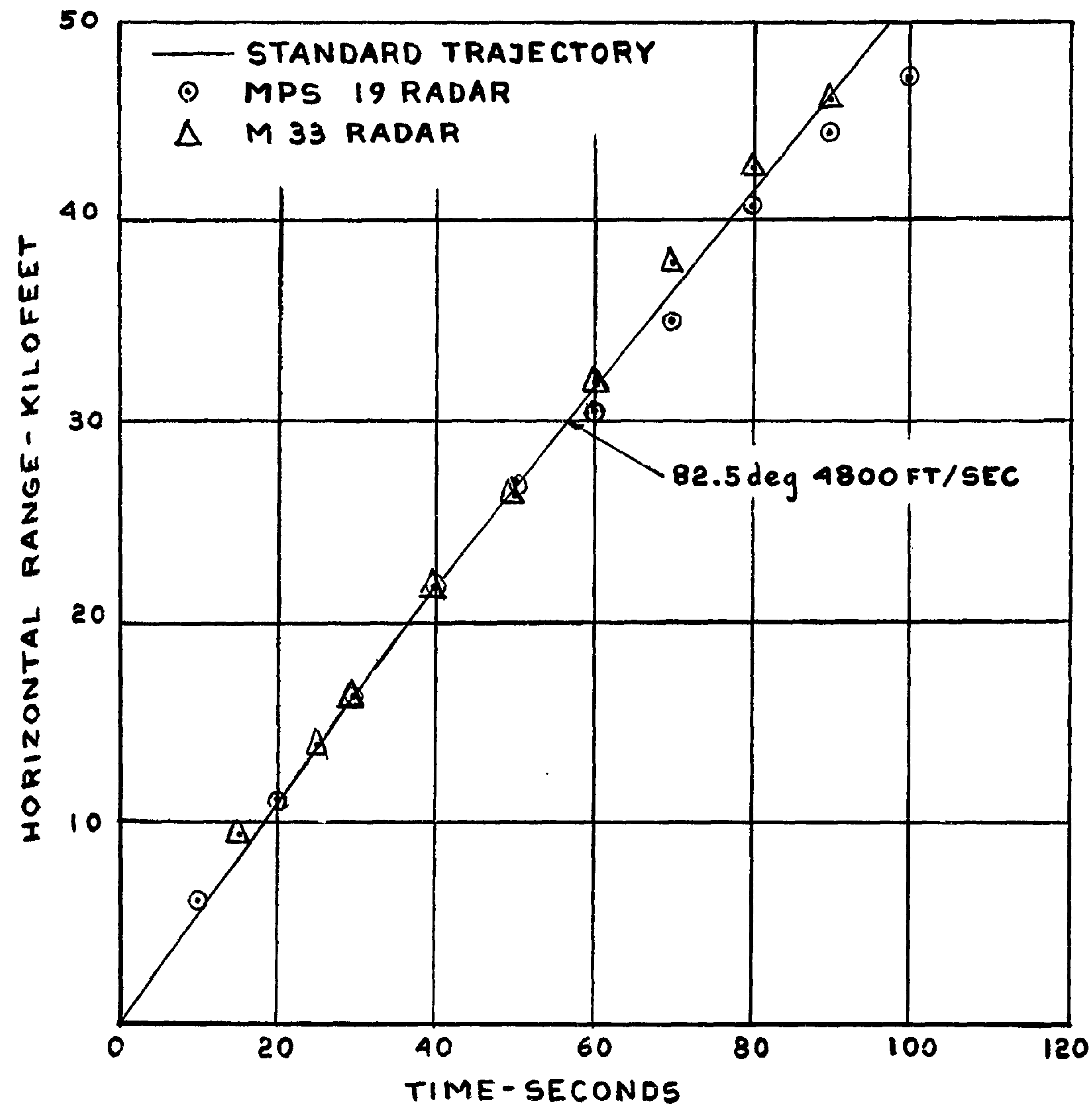


FIG. 5b MARTLET 2A SHOT SPARTA

RANGE VS TIME

SPARTA

5 JUNE, 1965 1322 HR AST

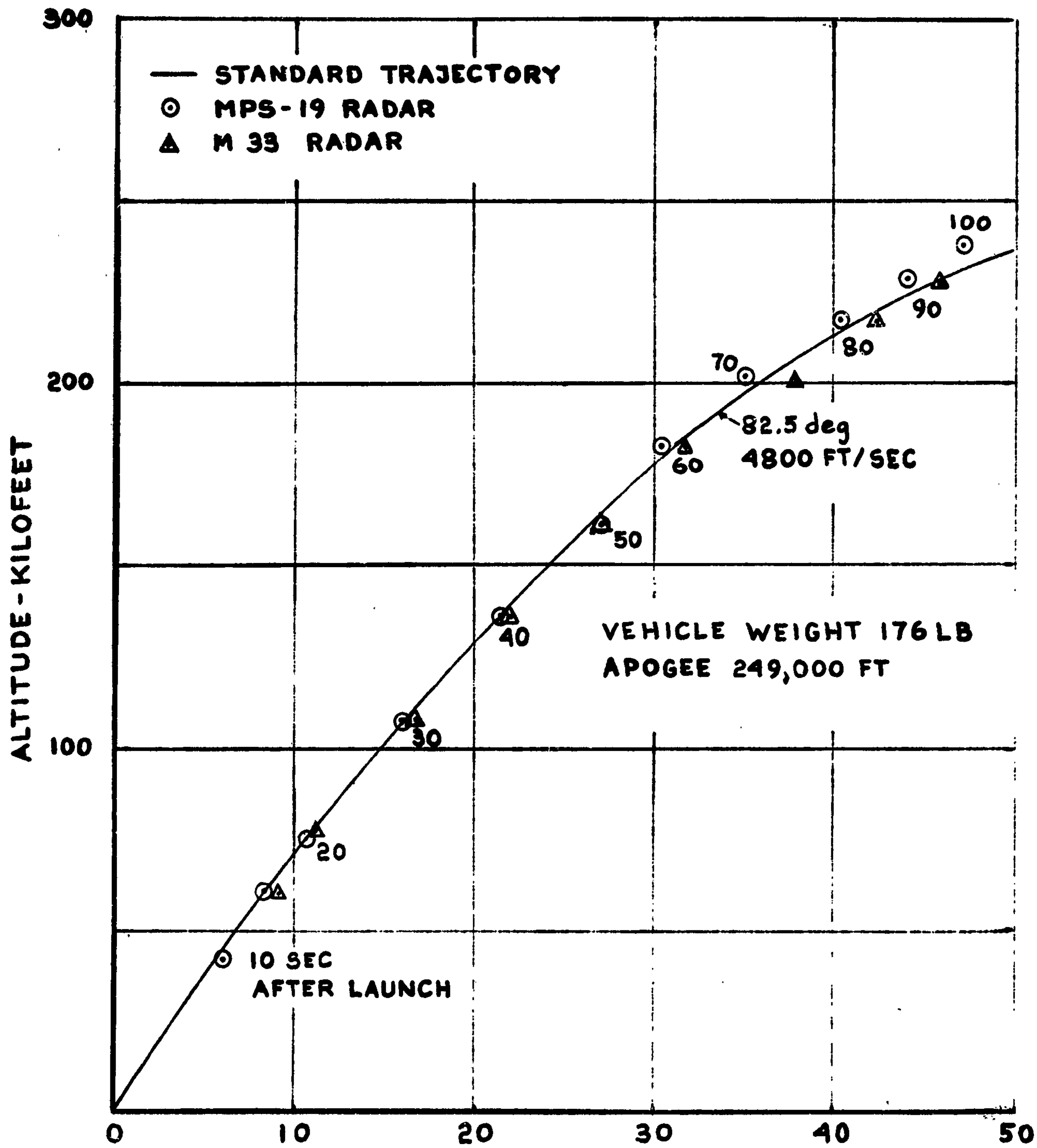


FIG.5c MARTLET 2A SHOT SPARTA

ALTITUDE VS RANGE

RANGE - KILOFEET

RADAR

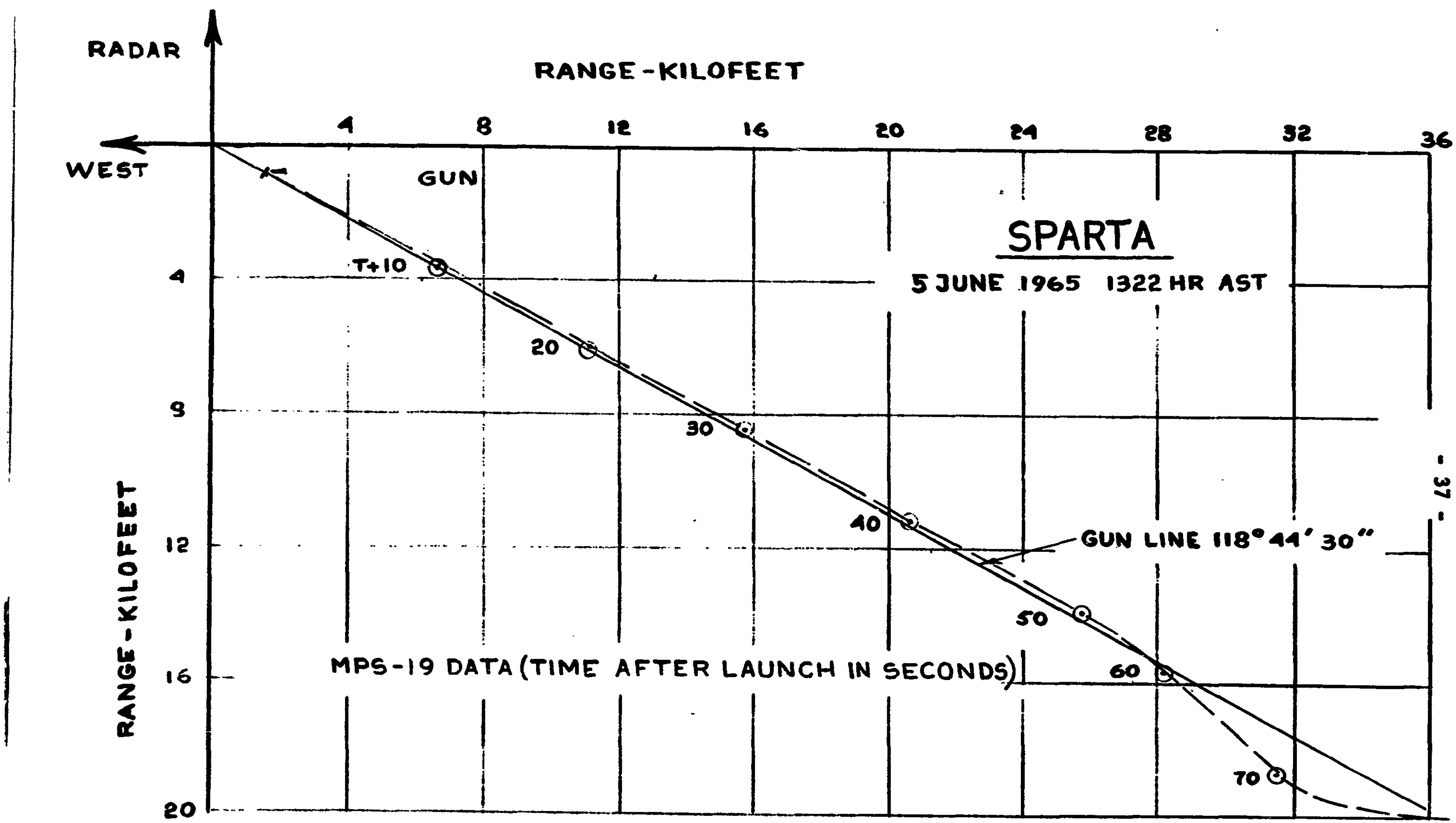


FIG. 5d PLAN VIEW OF MARTLET 2A - SPARTA TRAJECTORY

4.0 THE MARTLET 2C SERIES

4.1 Vehicle

The Martlet 2C vehicle designed for TMA release performed satisfactorily in the March test firings. It was therefore used again in this series without changes except for payload installations. The dimensions shown in Figs. 6a and b are the same as in the March series.

4.2 Payload

The mechanical TMA release valve system developed for the March program demonstrated its reliability in that series. For this reason the present series had on its program synoptic firings with consecutive shots to cover a time period from sunset to sunrise.

In addition to a payload of 5.5 lbs TMA, three of the Martlet 2C vehicles carried telemetry with temperature gauges and a single magnetometer mounted in the nose cone in a plane perpendicular to the longitudinal axis of the vehicle. (Fig. 6b). The magnetometer units were manufactured by Schoenstadt Instruments Inc. and modified by Harry Diamond Laboratory (HDL) for the high g environment. The output of the magnetometer corresponded to the component of the earth's magnetic field in the sensitive axis of the magnetometer. The output on a spinning

vehicle therefore tended to be sinusoidal and was used to modulate a single subcarrier oscillator of a 250 MHz fm-fm telemetry system. The transmitter was connected to an inductively loaded nose cap antenna in such a manner that the vehicle body became the primary radiator. The thermistor temperature gauge was used to sense the temperature of the magnetometer. The output of the gauge modulated a subcarrier oscillator.

4.3 Aerodynamics and Predicted Performance

Computed trajectories are given in Fig. 7 for a vehicle weight of 185 lb and launch elevations of 80 deg, 82.5 deg, and 85 deg at a muzzle velocity of 6,000 ft/sec.

4.4 Firing Program

Altogether twelve Martlet 2C vehicles were fired in three synoptic series.

The first series (Nos. 5 to 8: MARIUS, NERO, ELAGABULUS, FABIUS) consisted of 4 shots, each with a 5.5 lb TMA payload, fired during the night of June 3 to 4 from 8 p.m. to 3 a.m. In the second series (Nos. 14 to 17: LUCRETIA, OVID, CICERO, DIANA; June 9/10) four shots were fired during the night hours, with all but one vehicle (OVID) carrying HDL telemetry with temperature gauges and a magnetometer as well. During a third night (June 11/12) three more TMA release rounds were fired (Nos. 18 to 20: PLINY, QUINTUS, HADRIAN). Furthermore there

was one TMA daylight shot as a vehicle engineering test (No. 9, GRACCHUS, June 5).

Bad weather conditions prevalent throughout the series caused some delays in the program, and restricted photographic coverage in some cases. Trails, however, were obtained on all flights. Several TMA flights had lower apogees than expected and showed azimuth dispersion of up to 8 degrees. This dispersion is attributed to a bad barrel. The first barrel section had an eccentric rifling, all of which was not removed on smooth boring. This led to excessive barrel wear in the first twenty feet of barrel, resulting in gas leaks and asymmetric wear on the sabots. This in turn caused pusher plate cocking and large vehicle yaw, particularly severe as pressure increased. This is to be remedied by adding a liner.

In the three telemetry shots the magnetometer and the temperature gauges worked satisfactorily; the telemetry signals themselves were sometimes very weak and were received intermittently.

The flight results of the twelve rounds are summarized in Table III, and a detailed flight performance of each round is given in Section 4.5.

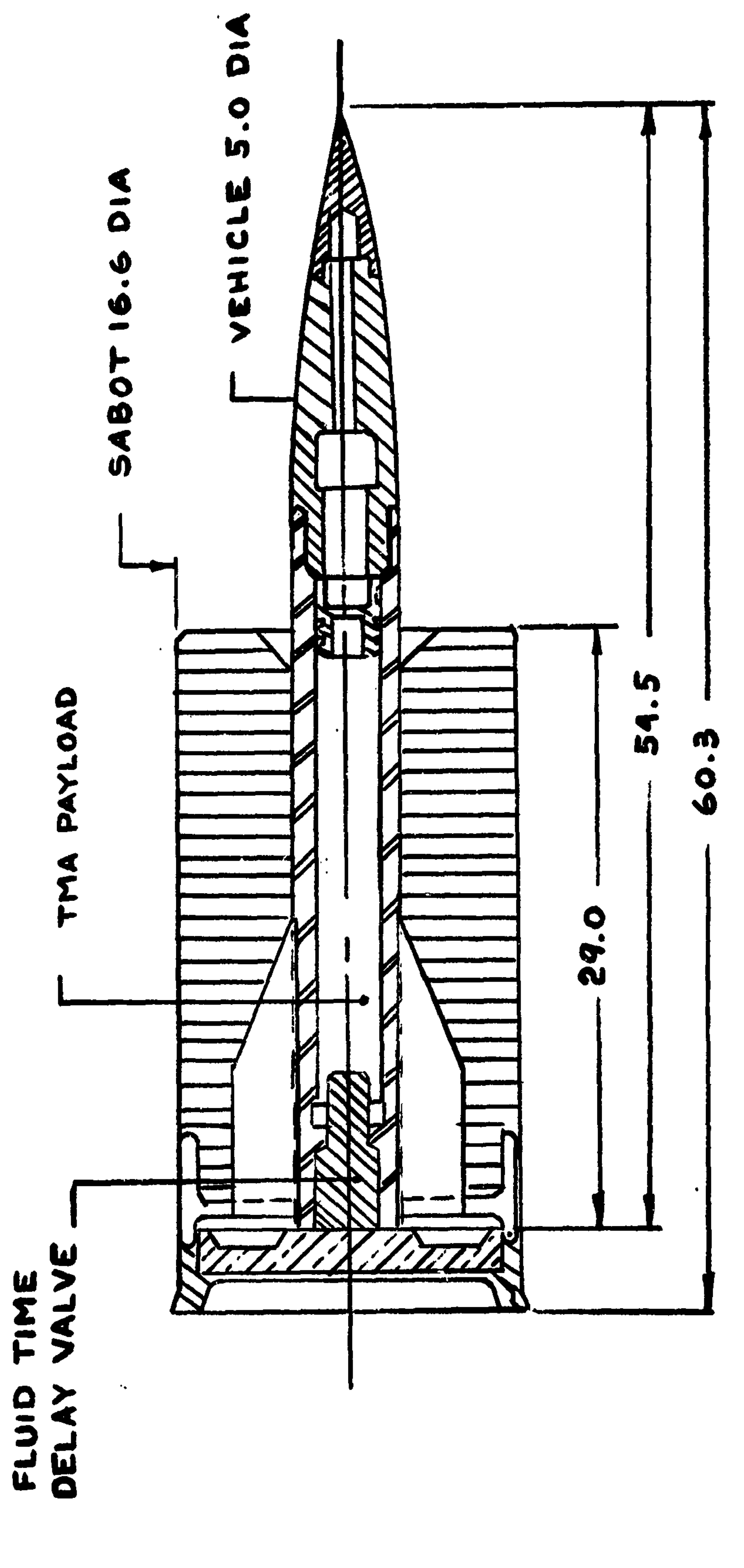


FIG. 6a MARTLET 2C - TMA PAYLOAD

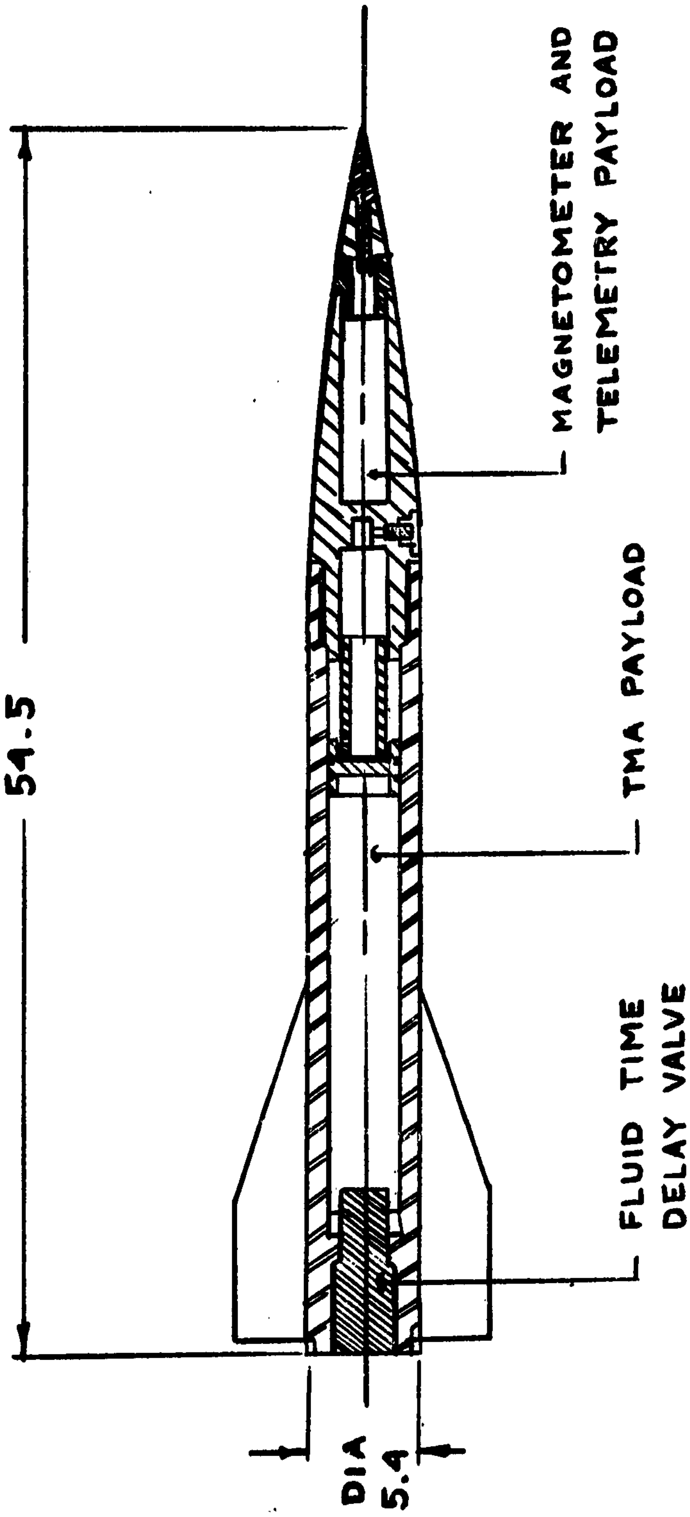


FIG. 6B MARTLET 2C

MAGNETOMETER - TMA - TELEMETRY

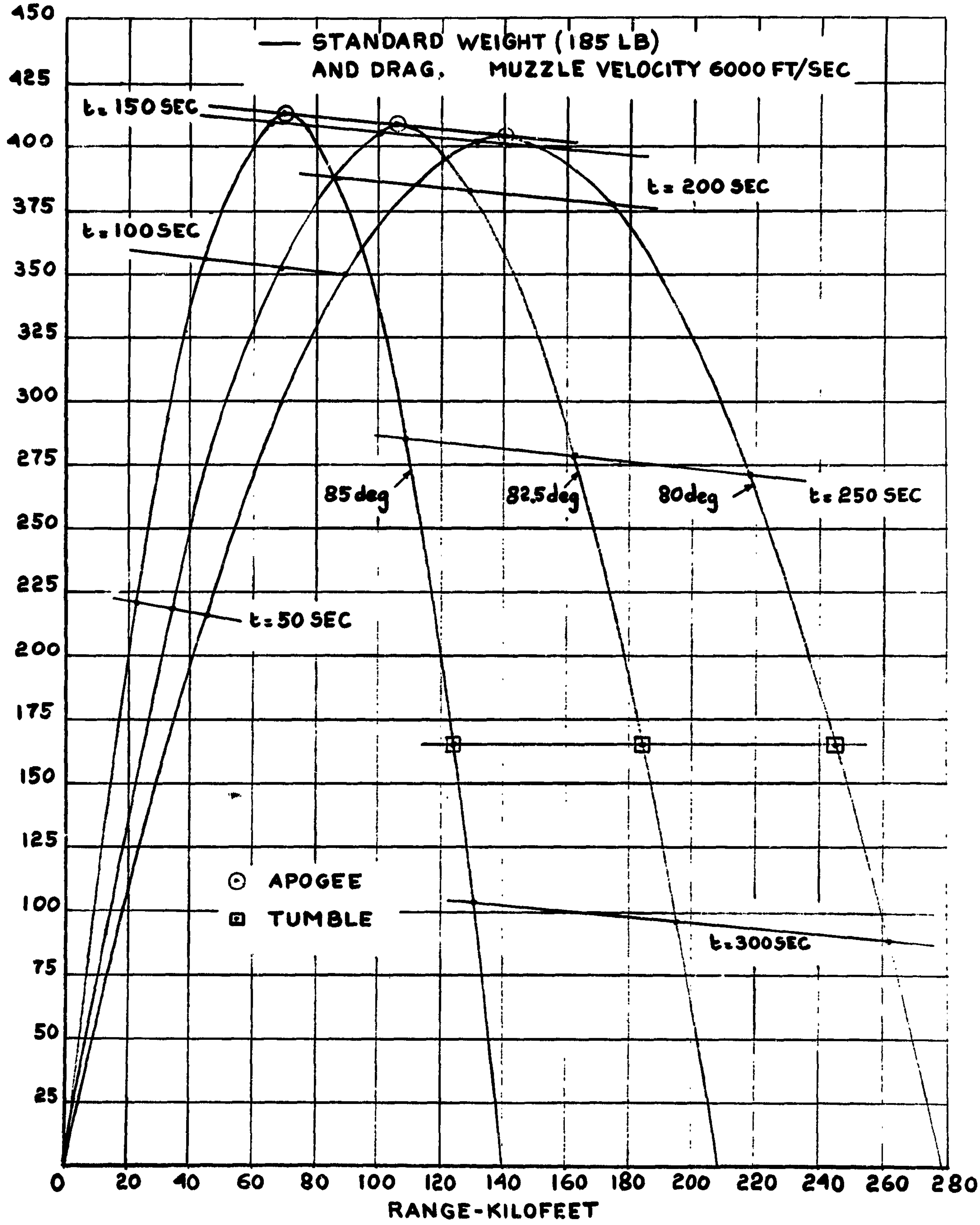


FIG. 7 MARTLET 2C TRAJECTORIES
FOR 6000 FT/SEC MUZZLE VELOCITY AND A VEHICLE WEIGHT OF 185 LB.

TABLE III

MAY/JUNE 1965 TEST PROGRAM - MARTLET 2C SERIES

Flight	Vehicle Description	Weight (lb)	Launch Data	Breech Pressure (psi)	Muzzle Velocity (ft/sec)	Apogee ft(km)	Comments
5(112) MARIUS 3/6/65 1957 hr AST QE 86.5 deg	Martlet 2C carrying 5.5 lb TMA ejecting from T + 65 sec to T + 170 sec.	Wv: 187.5 Ws: 413.0 C: 725 (M8M)	RD: 184.5 in RL: 80 tons ChV:39,200 in^3 Rec:36.5 in	St: 33,000 M11: 37,500	P: 4860 5950 - R: 5700	Radar 368,000 (111)	Successful round. Good TMA trail.
6(113) NERO 3/6/65 2241 hr AST QE 86.5 deg	Martlet 2C carrying 5.5 lb TMA ejecting from T + 65 sec to T + 170 sec.	Wv: 187.5 Ws: 411.5 C: 725 (M8M)	RD: 184.3 in RL: 60 tons ChV:39,150 in^3 Rec:37.5 in	St: 34,800 M11: 37,700	P: 6200 4800 - R: -	Radar 310,000 (94)	Successful round. Good TMA trail.
7(114) ELAGABULUS 4/6/65 0134 hr AST QE 86.5 deg	Martlet 2C carrying 5.5 lb TMA ejecting from T + 65 sec to T + 170 sec.	Wv: 187.0 Ws: 415.0 C: 735 (M8M)	RD: 189 in RL: 17 tons ChV:40,160 in^3 Rec:38.8 in	St: 35,600 M11: 36,700	P: 5750 6090 5920 R: 5850	Radar 391,000 (119)	Successful round. TMA trail clearly seen for a long time.
8(115) FABIUS 4/6/65 0317 hr AST QE 86.5 deg	Martlet 2C carrying 5.5 lb TMA ejecting from T + 65 sec to T + 170 sec.	Wv: 187.5 Ws: 414.0 C: 745 (M8M)	RD: 189 in RL: 30 tons ChV:40,160 in^3 Rec:39.0 in	St: 36,500 M11:37,500	P: 5130 - - R: 5620	Radar 359,000 (110)	Successful round. Good TMA trail.
9(116) GRACCHUS 5/6/65 1100 hr AST QE 82.5 deg	Martlet 2C carrying 5.5 lb TMA ejecting from T + 65 sec to T + 170 sec.	Wv: 187.5 Ws: 415.0 C: 750 (M8M)	RD: 189 in RL: 25 tons ChV:40,160 in^3 Rec:37.5 in	St: 36,500 M11: 38,300	P: 6460 7050 - R: 5750 WF: 5810	Radar 377,000 (115)	Successful flight. Good camera results obtained on this daylight round. Vehicle engineering test (not for wind evaluation).

Flight	Vehicle Description	Weight (lb)	Launch Data	Breech Pressure (psi)	Muzzle Velocity (ft/sec)	Apogee ft(km)	Comments
14(121) LUCRETIA 9/6/65 1851 hr AST QE 82.5 deg	Martlet 2C carrying 5.5 lb TMA and HDL 250 MHz telemetry with temperature gauges and magnetometer.	Wv: 189.0 Ws: 415.0 C: 750 (M8M)	RD: 190.625 in RL: 15 tons ChV:40,500 in^3 Rec:37.5 in	St: 36,500 Mk6: 38,000 M11: 38,900	P: 6060 6270 6160 R: 5820	Radar 387,000 (118)	Successful flight. Magnetometer and temperature gauge functioned. No wind data, owing to bad weather conditions.
15(122) OVID 9/6/65 2157 hr AST QE 82.5 deg	Martlet 2C carrying 5.5 lb TMA ejecting from T + 65 sec to T + 170 sec.	Wv: 188.0 Ws: 414.0 C: 750 (M8M)	RD: 192 in RL: 25 tons ChV:40,790 in^3 Rec:38.0 in	St: 34,800 Mk6: 36,900 M11: 38,500	P: 6080 6150 6120	Radar 340,500 (104)	Successful round. Good trail.
16(122) CICERO 9/6/65 2357 hr AST QE 82.5 deg	Martlet 2C carrying 5.5 lb TMA and HDL 250 MHz telemetry. TMA to be ejected at T + 65 sec. Telemetry to commence transmitting at launch.	Wv: 189.5 Ws: 417.5 C: 760 (M8M)	RD: 192 in RL: 17 tons ChV:40,790 in^3 Rec:38.5 in	St: 35,200 M11: 39,800	P: 5930 5970 5950 R: 5600	Radar 350,500 (107)	Good flight. Telemetry signals weak. Magnetometer and temperature gauge functioned. Good trail.
17(124) DIANA 10/6/65 0235 hr AST QE 82.5 deg	Martlet 2C carrying 5.5 lb TMA and HDL 250 MHz telemetry. TMA to be ejected at T + 65 sec. Telemetry to commence transmitting at launch.	Wv: 189.0 Ws: 416.5 C: 780 (M8M)	RD: 192 in RL: 20 tons ChV:40,790 in^3 Rec:39.0 in	St: 43,200 M11: 46,300	P: 5170 5910 - R: 5660	Radar 357,600 (109)	Telemetry signals very weak. Magnetometer and temperature gauge functioned. Antenna evidently lost. No wind data due to cloud conditions.

TABLE III (Cont'd)

Flight	Vehicle Description	Weight (lb)	Launch Data	Breech Pressure (psi)	Muzzle Velocity (ft/sec)	Apogee ft (km)	Comments
18(125) PLINY 11/6/65 2107 hr AST QE 82.5 deg	Martlet 2C carrying 5.5 lb TMA ejecting from T + 65 sec to T + 170 sec.	Wv: 187.25 Ws: 414.25 C: 780 (M8M)	RD: 192 in RL: 17 tons ChV:40,790 in^3 Rec:39.75 in	St: 41,800 Mk6: 46,500 M11: 44,800	P: 6850 6140 - R: 6160	Radar 436,000 (133)	Successful shot. Good trail coverage.
19(126) QUINTUS 12/6/65 0300 hr AST QE 85.0 deg	Martlet 2C carrying 5.5 lb TMA ejecting from T + 65 sec to T + 170 sec.	Wv: 187.25 Ws: 414.75 C: 790 (M8M)	RD: 192 in RL: 18 tons ChV:40,795 in^3 Rec:40.5 in	St: 45,200 Mk6: 45,700 M11: 49,300	P: 6060 6050 6060 R: 6160	Radar 444,000 (135)	Vehicle flew despite pusher plate damage. Due to bad cloud conditions, no wind data obtained. New apogee record.
20(127) HADRIAN 12/6/65 0431 hr AST QE 85 deg	Martlet 2C carrying 5.5 lb TMA ejecting from T + 65 sec to T + 170 sec.	Wv: 185.5 Ws: 418.0 C: 780 (M8M)	RD: 192 in RL: 16 tons ChV:40,790 in^3 Rec:40.25 in	St: 40,000 Mk6: 42,100 M11: 44,100	P: 6050 5600 - R: 6140	Radar 438,000 (133)	Successful shot. Good TMA trail coverage.

Wv: Vehicle Weight
Ws: Shot Weight
C: Charge Weight

RD: Ram Distance
RL: Ram Load
Chv: Chamber Volume
Rec: Recoil

P: Probe 1st Fig. Left
2nd. Fig. Right
3rd. Fig. Average
R: Radar
WF: West Fastax
EF: East Fastax

S: Double Smear

St: Strain Gauge
Mk6:, M11: Crusher Gauges

4.5 Detailed Flight Performance

4.5.1 Round No. 5 - MARIUS

Date: 3 June 1965 - 1957 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb TMA payload to be ejected from T + 65 to T + 170 seconds.

Purpose of Test: Synoptic measurements of wind profiles.

Weights:	Vehicle	187.5 lb
	Pusher and Obturator	122.5 lb
	Sabot	101.0 lb
	Shot Weight	411.0 lb

Centre of Gravity: 22.3 in. from base.

Launch Data:

Charge Weight	725 lb M8M (8 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	86 degrees
Crusher Gauges	M11 - 4
Ram Distance	184.5 in
Ram Load	80 tons
Chamber Volume	39,205 in^3
Recoil	36.5 in
Breech Pressure	M11 37,500 psi
	Strain 33,000 psi(Fig. 8)
Muzzle Velocity Probe	left 4,860 ft/sec
	right 5,950 ft/sec

Radar Records:

M-33 radar followed the vehicle by manual tracking to T + 60 seconds. The MPS-19 acquired at T + 5 seconds and tracked to T + 104 seconds, near apogee (data in Appendix A). Splash-down was observed with a total range of 103,000 ft at an azimuth of 122.2 degrees.

Trajectory:

The radar data have been plotted in Fig. 8a to 8c and compared with a standard trajectory for 86 deg and 5,700 ft/sec muzzle velocity. The agreement is satisfactory. Note again that no exact conclusion can be drawn for the muzzle velocity, since a higher velocity can always be assumed in conjunction with higher drag.

The apogee was found to be 369,000 ft = 112 kilometers. This is in good agreement with the photo-theodolite data obtained as follows:

Tobago	112 kilometers
St. Vincent	109 kilometers
Grenada	114 kilometers

The range of 103,500 ft as measured by MPS-19 is also in agreement with the theoretical result.

TMA Trail Results:

The TMA payload and the K-24 cameras performed satisfactorily. Wind shear data were obtained from 102 km to 114 km (Chapter 8).

Summary:

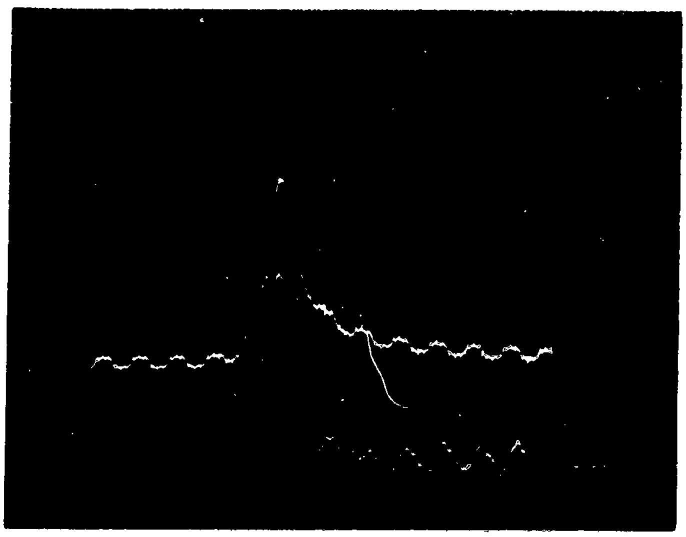
The round was successful. Good trajectory and TMA trail so that wind profile data could be obtained.

MARIUS

3 JUNE 1965 - 1957 HR AST

8,700 psi per cm (division)

BREECH PRESSURE



TIME

20 milliseconds per cm (division)

Maximum Breech Pressure: Pmax = 33,000 psi

Fig. 8 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND MARIUS

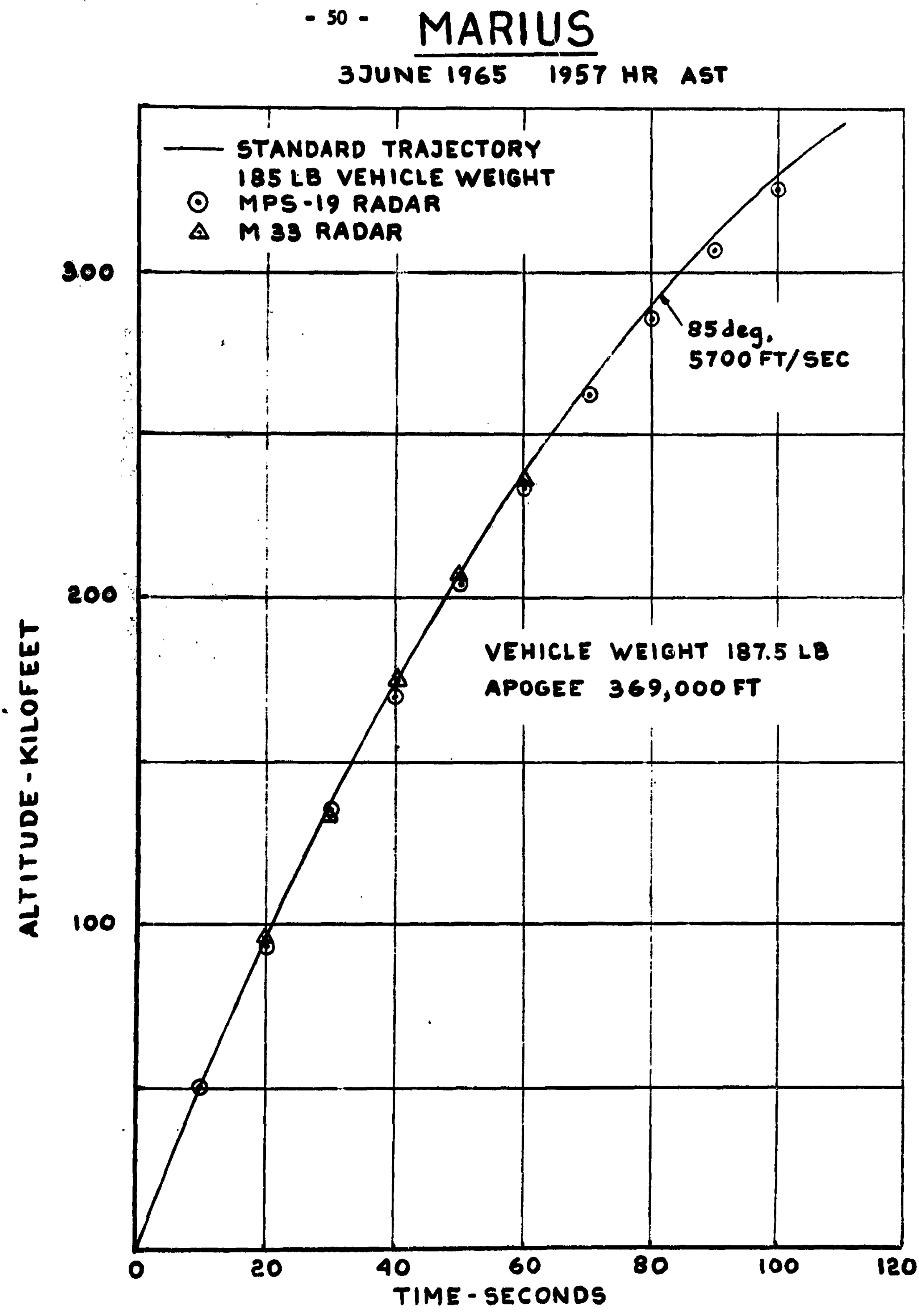


FIG. 8a MARTLET 2C SHOT MARIUS
ALTITUDE VS TIME

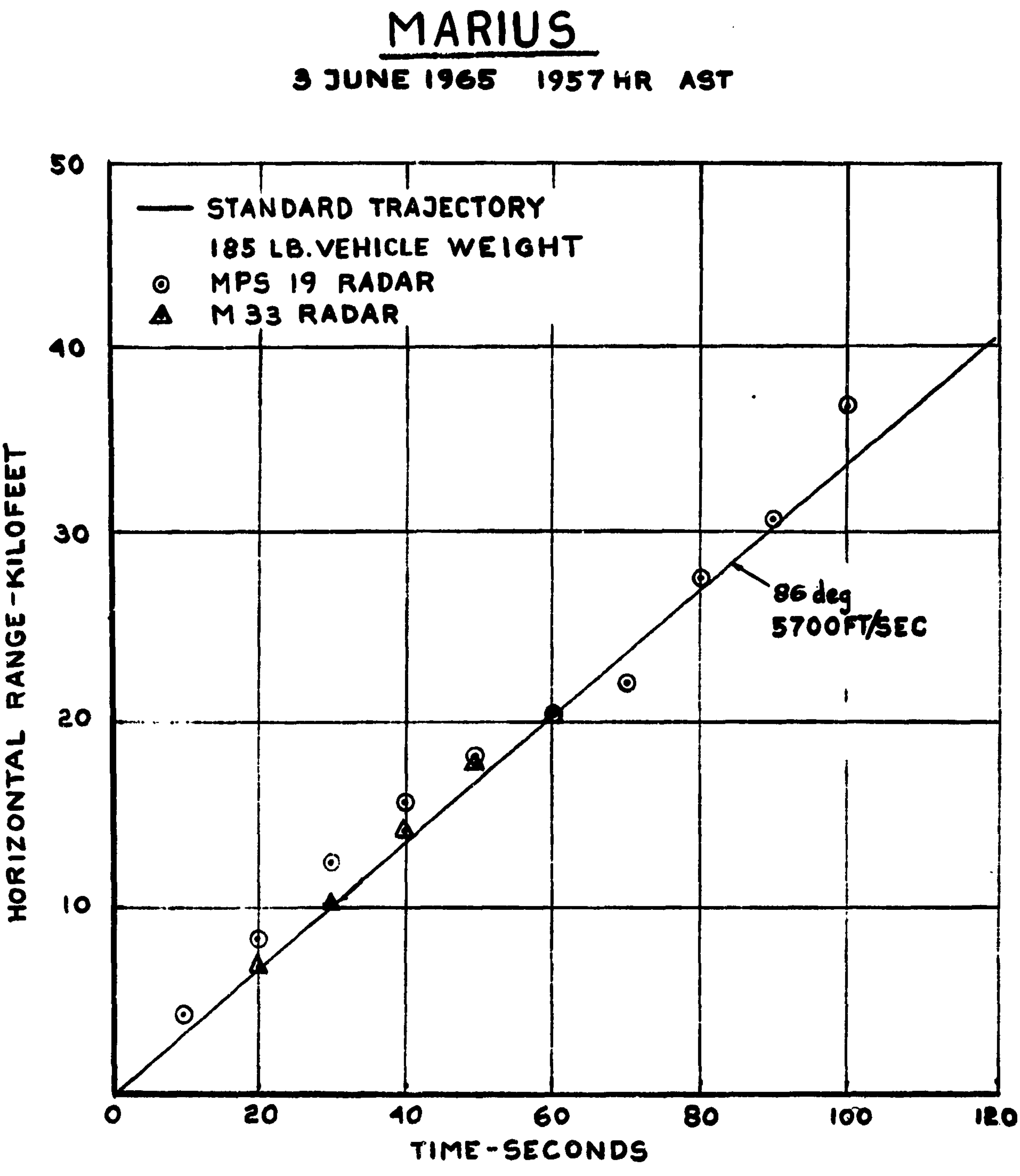


FIG. 8b. MARTLET 2C SHOT MARIUS

RANGE VS TIME

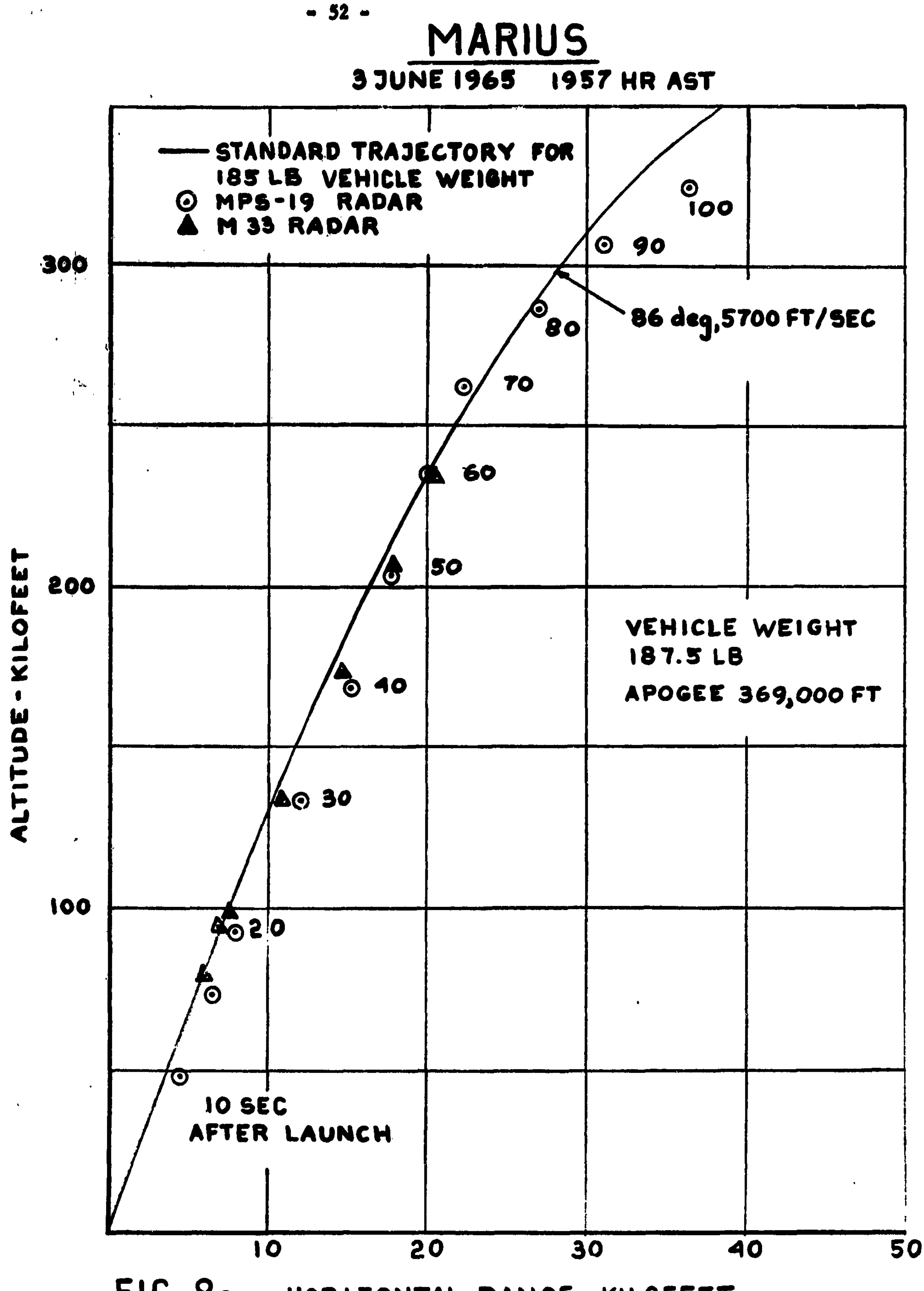


FIG. 8c ALTITUDE VS RANGE

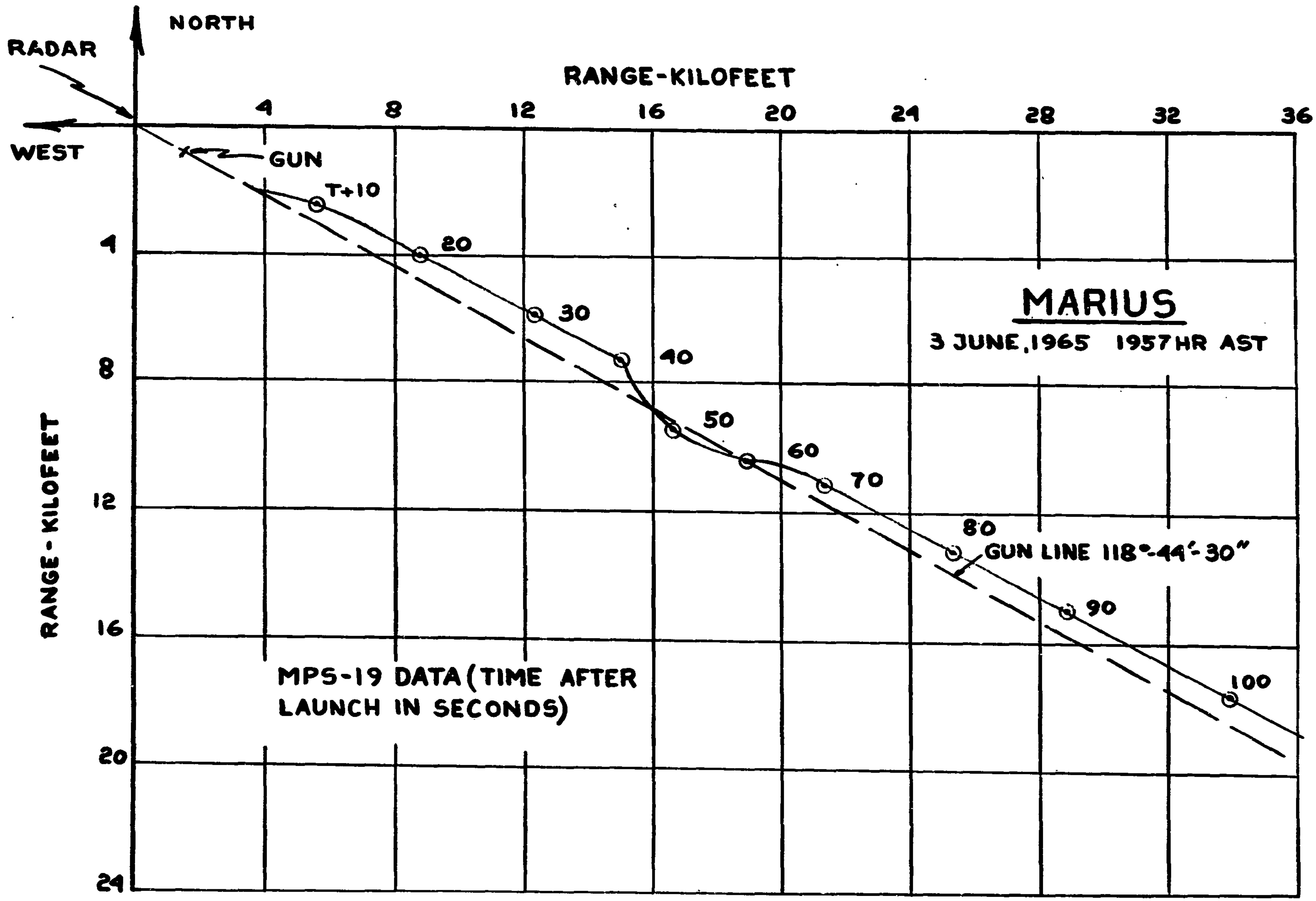


FIG. 8d PLANVIEW OF MARTLET 2C - MARIUS TRAJECTORY

4.5.2 Round No. 6 - NERO

Date: 3 June, 1965 - 2241 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb TMA payload to be ejected from T + 65 to T + 170 seconds.

Purpose of Test: Synoptic measurement of wind profiles.

Weights:

Vehicle	187.5 lb
Pusher and Obturator	123.0 lb
Sabot	101.0 lb
Shot Weight	411.5 lb

Centre of Gravity: 22 in. from base.

Launch Data:

Charge Weight	725 lb M8M (8 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	86 degrees
Crusher Gauges	M11 - 4
Ram Distance	184.3 in
Ram Load	60 tons
Chamber Volume	39,152 in^3
Recoil	37.5 in
Breech Pressure	M11 37,700 psi Strain 34,800 psi (Fig. 9)
Muzzle Velocity Probe	left 6,200 ft/sec right 4,800 ft/sec

Radar Records:

The MPS-19 radar suffered a power failure so that only M-33 radar data were available.

Trajectory:

The M-33 radar results are plotted in Figs. 9a to 9c. They are in good agreement with a standard trajectory of 5,300 ft/sec velocity and an elevation angle of 85 deg. The recorded elevation was 86 deg but the horizontal range data indicate that

the effective launch elevation was 85 deg.

Since a muzzle velocity of 5,300 ft/sec is extremely low for the charge weight used and the maximum breech pressure obtained, it can be assumed that the drag was higher than standard. An increase in drag of 25% would require a muzzle velocity of 5,600 ft/sec in order to obtain approximately the measured trajectory.

No plan view of the trajectory could be plotted since no azimuth data were available. The apogee was 310,000 ft = 94.5 km, and the estimated range 105,000 ft. The apogee figure is in agreement with phototheodolite results (94 km).

TMA Trail Results:

The TMA payload performed well and good K-24 photographs were obtained. The resulting wind shear data are given in Chapter 8 for an altitude range of 88 to 94 km.

Summary:

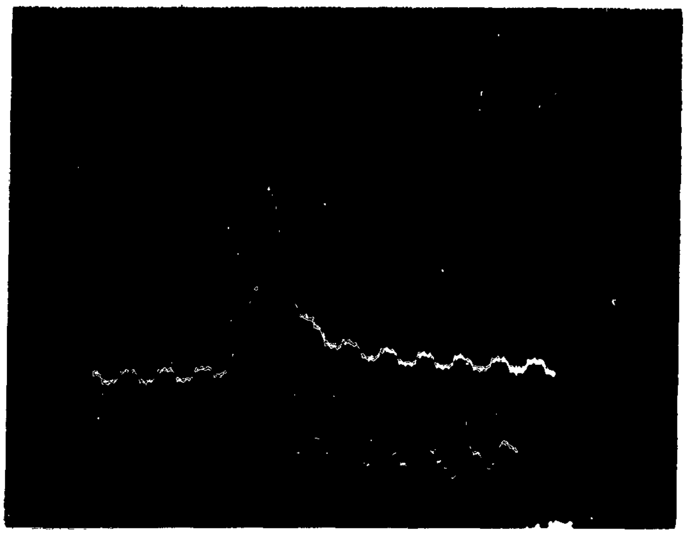
The apogee was lower than expected, probably owing to increased drag caused by pusher plate cocking and large vehicle yaw. Otherwise, it was a successful round.

NERO

3 JUNE 1965 - 2241 HR AST

8,700 psi per cm (division)

BREECH PRESSURE



TIME

20 milliseconds per cm (division)

Maximum Breech Pressure: Pmax = 34,800 psi

Fig. 9 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND NERO

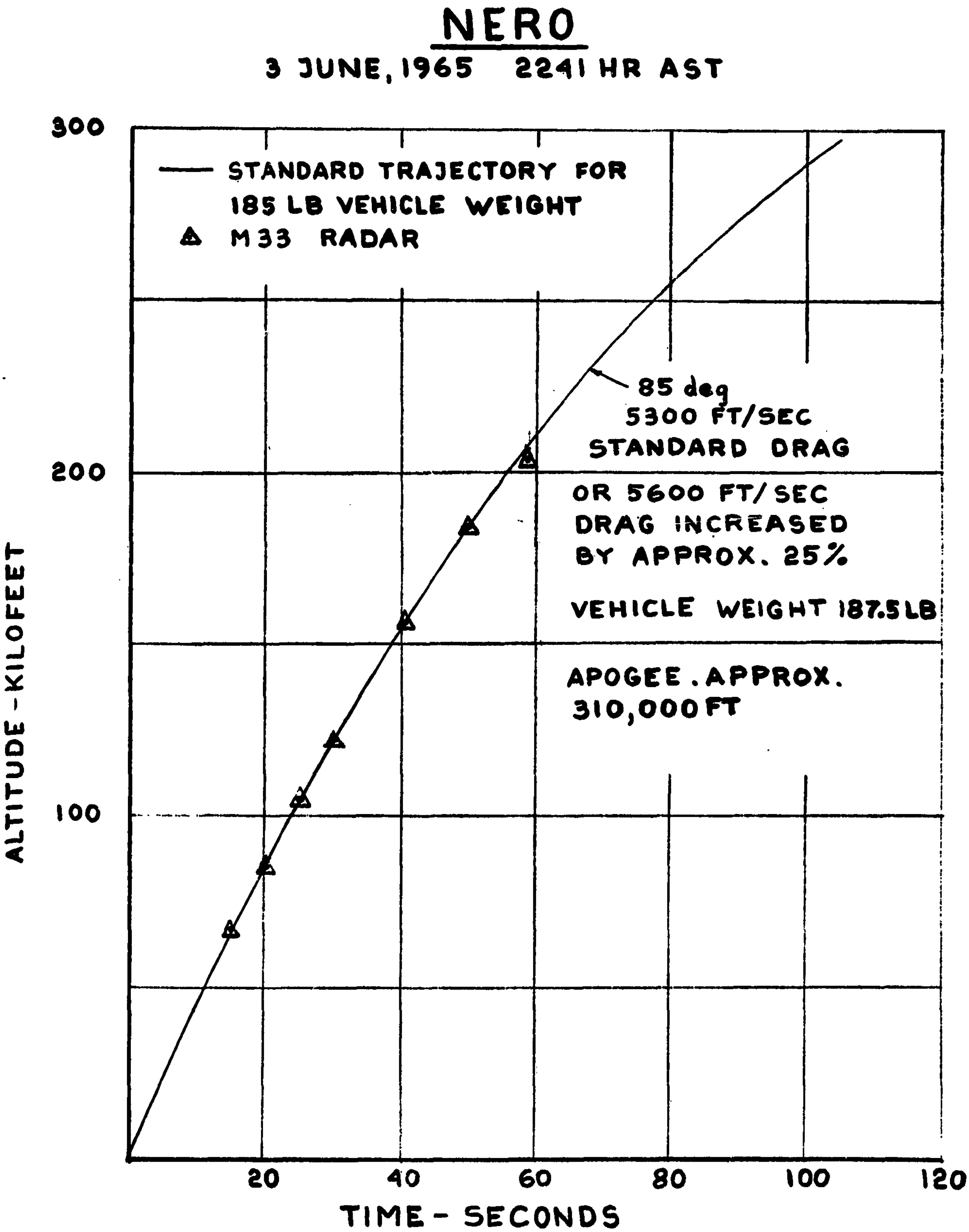


FIG. 9a MARTLET 2C SHOT NERO
ALTITUDE VS TIME

NERO

3 JUNE, 1965 2241 HR AST

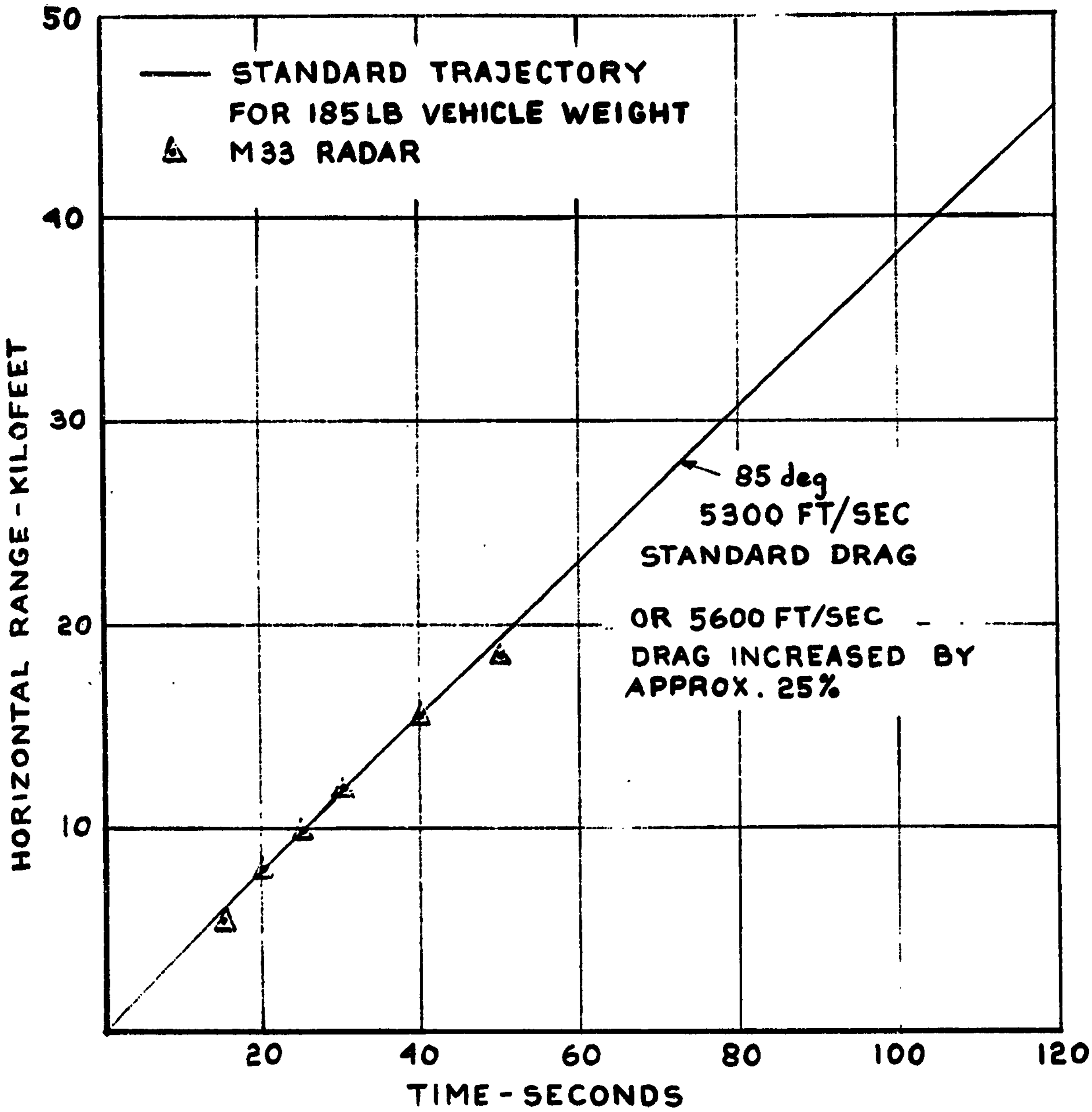


FIG. 9b MARTLET 2C SHOT NERO

RANGE VS TIME

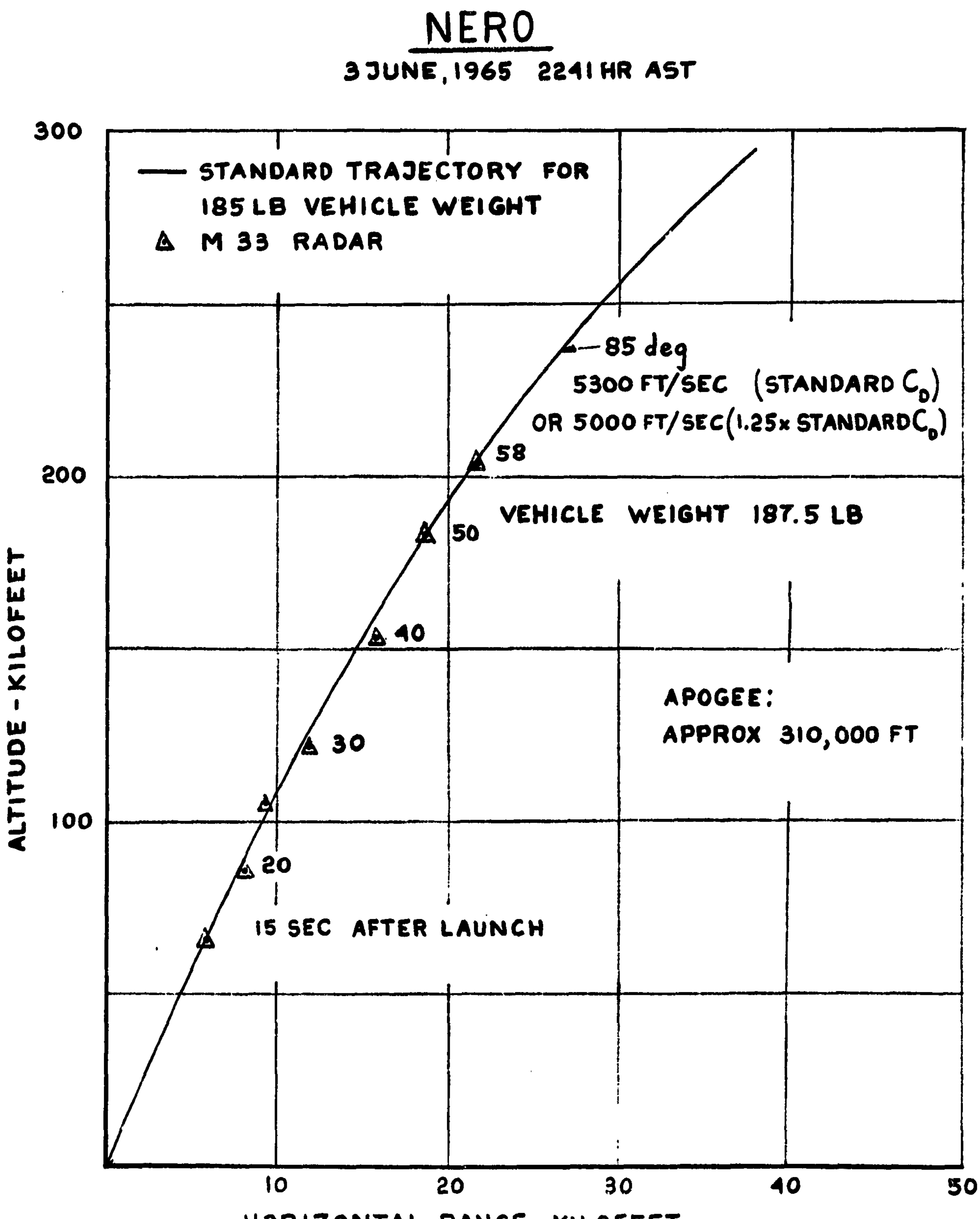


FIG. 9c MARTLET 2C SHOT NERO
ALTITUDE VS RANGE

4.5.3 Round No. 7 - ELAGABULUS

Date: 4 June, 1965 - 0134 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb TMA payload ejecting from T + 65 to T + 170 seconds.

Purpose of Test: Synoptic measurements of wind profiles.

Weights:

Vehicle	187.0 lb
Pusher and Obturator	123.0 lb
Sabot	105.0 lb
Shot Weight	415.0 lb

Centre of Gravity: 22 in. from base.

Launch Data:

Charge Weight	735 lb M8M (8 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	86 degrees
Crusher Gauges	M11 - 4
Ram Distance	189 in
Ram Load	17 tons
Chamber Volume	40,160 in^3
Recoil	38.8 in
Breech Pressure	M11 36,700 psi Strain 35,600 psi
Muzzle Velocity Probe	left 5,750 ft/sec right 6,090 ft/sec

Radar Records:

Both the M-33 and MPS-19 radars tracked the vehicle to approximately 300,000 ft.

Trajectory:

The radar data are in agreement with a standard trajectory for 5,900 ft/sec at 86 deg, except at altitudes near apogee where the radar data of the horizontal range appear to be too small (Figs. 10a to 10d).

An apogee value of 391,000 ft = 119 kilometers as derived from the radar data agrees with the phototheodolite data of Tobago (121 km) and St. Vincent (120 km) whereas Grenada reported only 101 km.

Estimated total range, 108,000 ft.

Trail Results:

Payload and K-24 camera performance was satisfactory. The trail was clearly seen for a long time. Good wind data were obtained over an altitude range of 30 km (91 km to 121 km). The results are given in Chapter 8.

Summary:

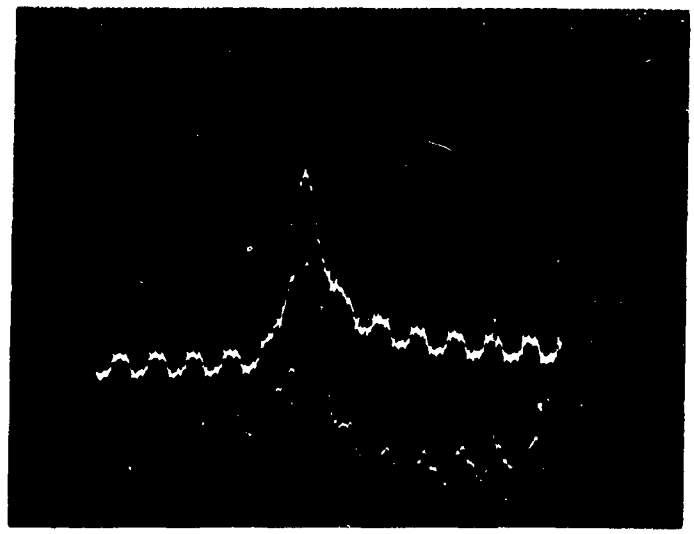
This was a successful round, in regard to vehicle and payload performance as well as wind shear results.

ELAGABULUS

4 JUNE 1965 - 0134 HR AST

8,700 psi per cm (division)

BREECH PRESSURE



TIME

20 milliseconds per cm (division)

Maximum Breech Pressure: Pmax = 35,600 psi

Fig. 10 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND ELAGABULUS

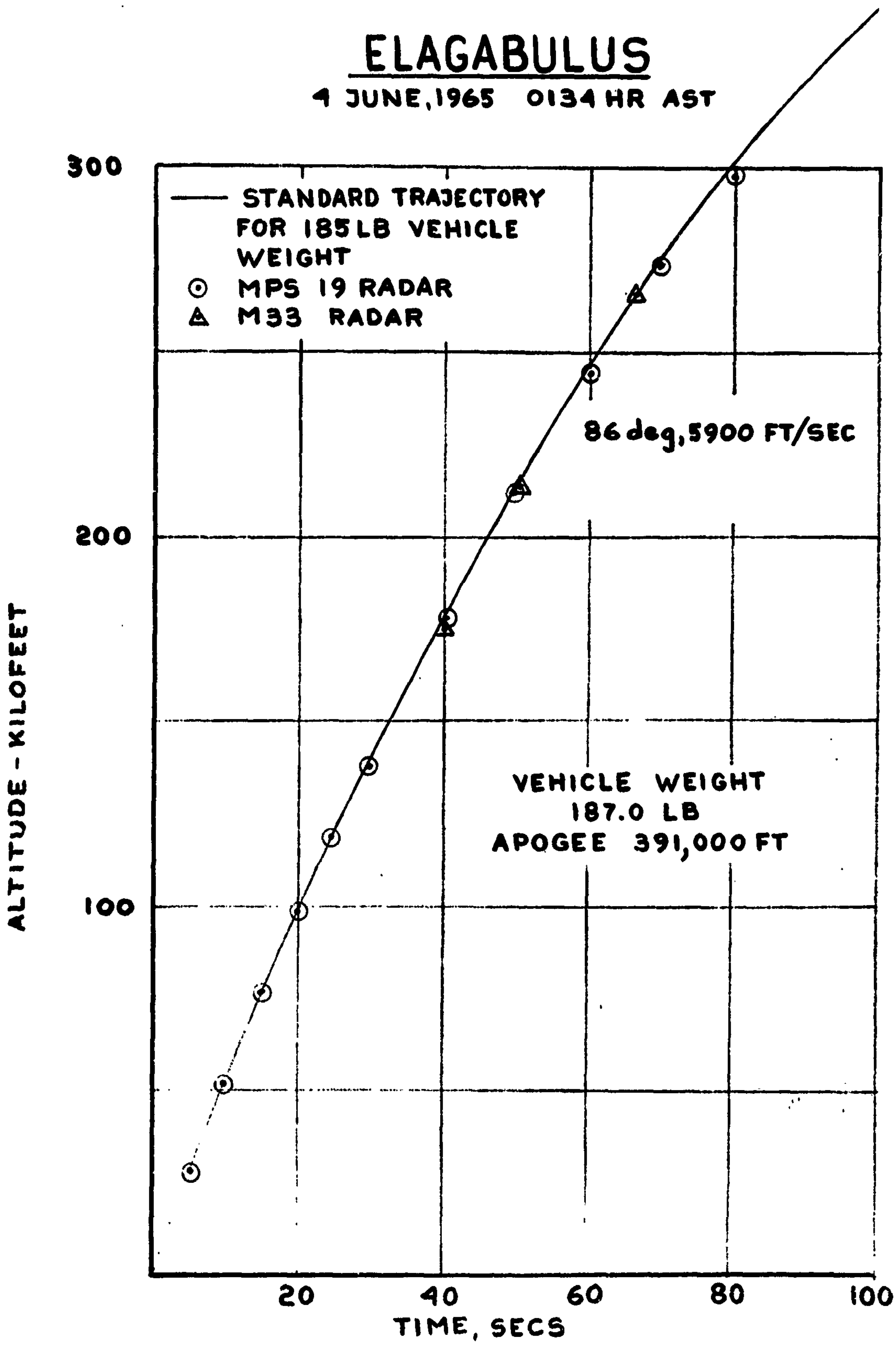


FIG.10a MARTLET 2C SHOT ELAGABULUS
ALTITUDE VS TIME

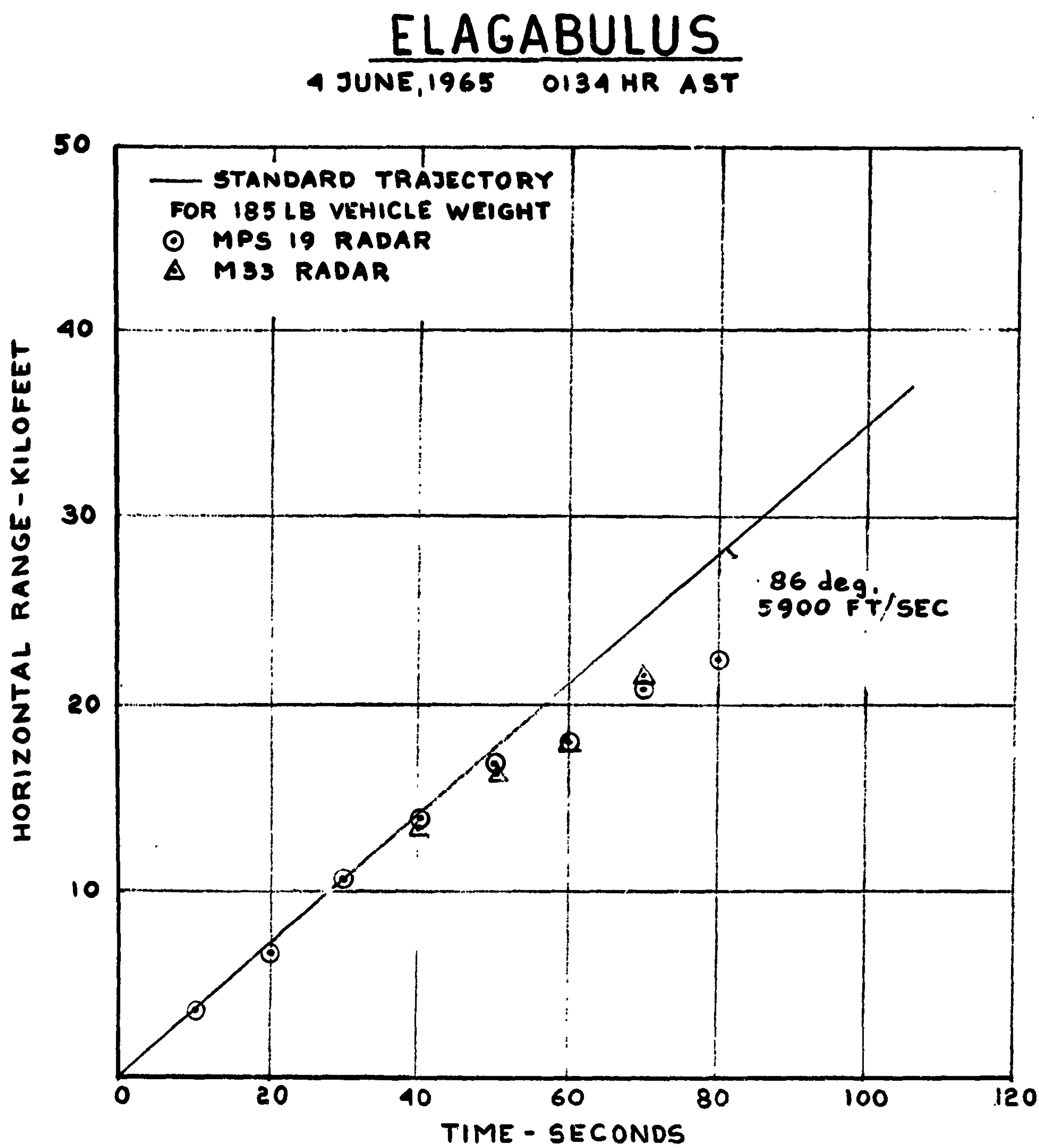


FIG. 10b MARTLET 2C SHOT ELAGABULUS
RANGE VS TIME

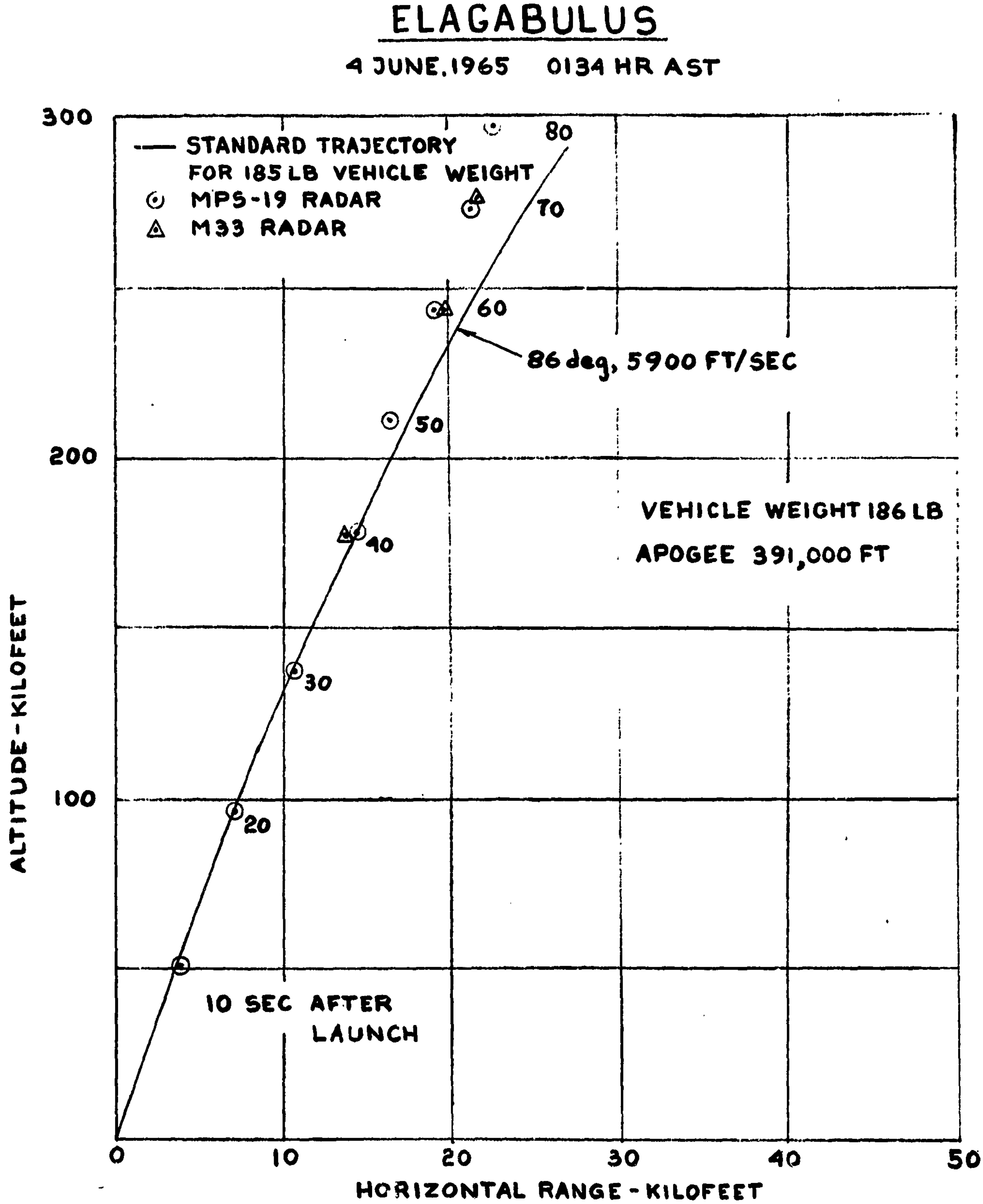


FIG. 10c MARTLET 2C SHOT ELAGABULUS

ALTITUDE VS RANGE

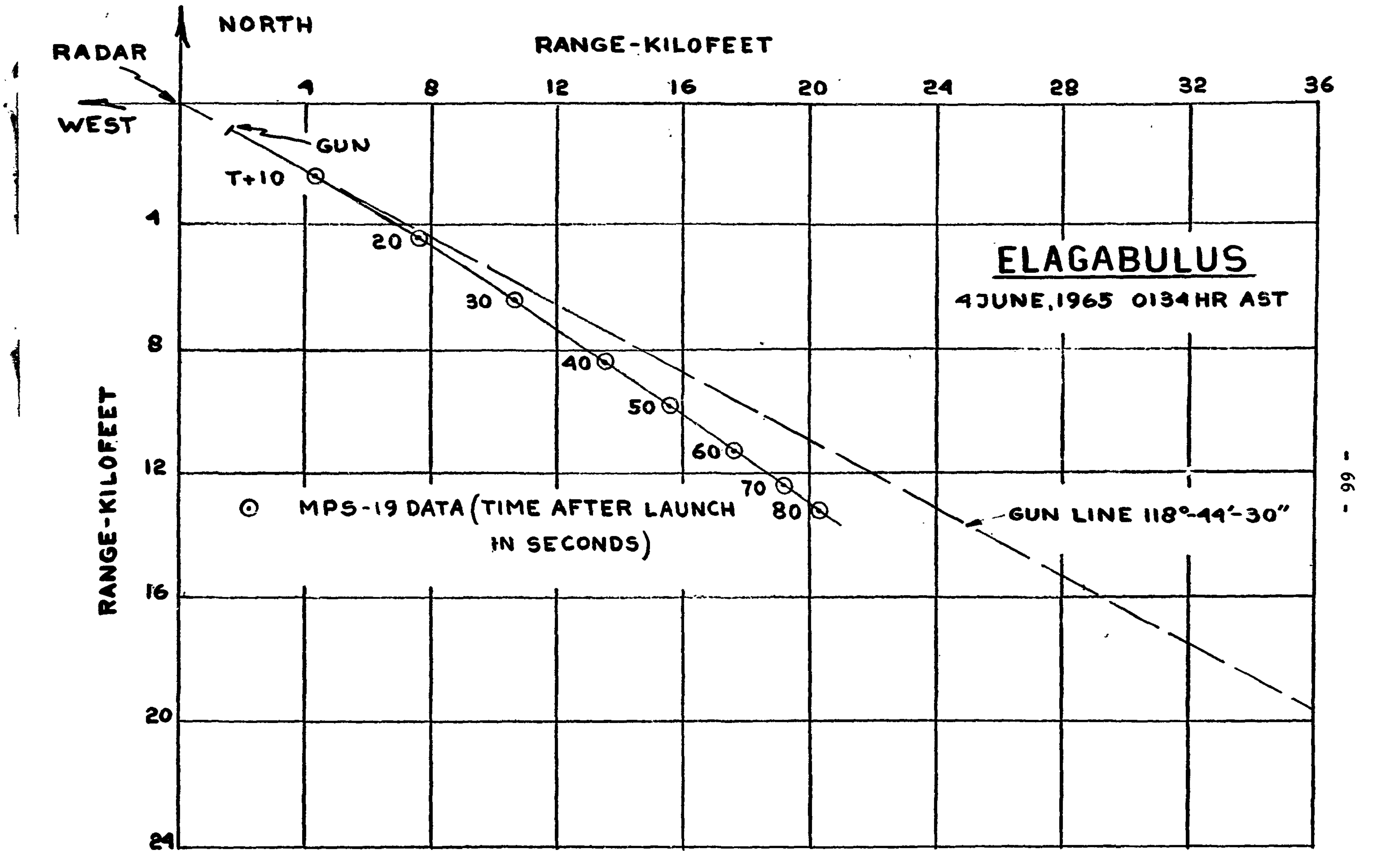


FIG. 10d PLAN VIEW OF MARTLET 2C ELAGABULUS TRAJECTORY

4.5.4 Round No. 8 - FABIUS

Date: 4 June, 1965 - 0317 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb TMA to be ejected from T + 65 to T + 170 seconds.

Purpose of Test: Synoptic measurements of wind profiles.

Weights:

Vehicle	187.5 lb
Pusher and Obturator	122.5 lb
Sabot	104.0 lb
Shot Weight	414.0 lb

Centre of Gravity: 22 in. from base.

Launch Data:

Charge Weight	745 lb M8M (8 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	86 degrees
Crusher Gauges	M11 - 4
Ram Distance	189 in
Ram Load	30 tons
Chamber Volume	40,160 in^3
Recoil	39.0 in
Breech Pressure	M11 37,500 psi
	Strain 36,500 psi (Fig. 11)
Muzzle Velocity Probe	left 5,130 ft/sec

Radar Records:

Both the M-33 and MPS-19 radars tracked the vehicle almost to apogee. The tracks showed that the vehicle was flying considerably off azimuth (Fig. 11d). The recovered pusher plate indicated that this was apparently the result of plate cocking and vehicle yaw, caused by the eccentric rifling of the barrel as explained in 4.4.

Trajectory:

The radar results are plotted in Figs. 11a to 11d and compared with the standard drag trajectory for 5,620 ft/sec at 86 deg. This muzzle velocity if not realistic; since the vehicle apparently left the gun at an angle of attack, a higher drag must be expected. For 25% drag increase, a muzzle velocity of 5,900 ft/sec would result. This is a value more in accordance with the given charge weight and the resulting maximum breech pressure.

The apogee was found to be 360,000 ft = 110 kilometers. This is in agreement with the average of theodolite data obtained at Tobago (120 km), St. Vincent (102 km) and Grenada (104 km).

Estimated total range = 100,000 ft.

Summary:

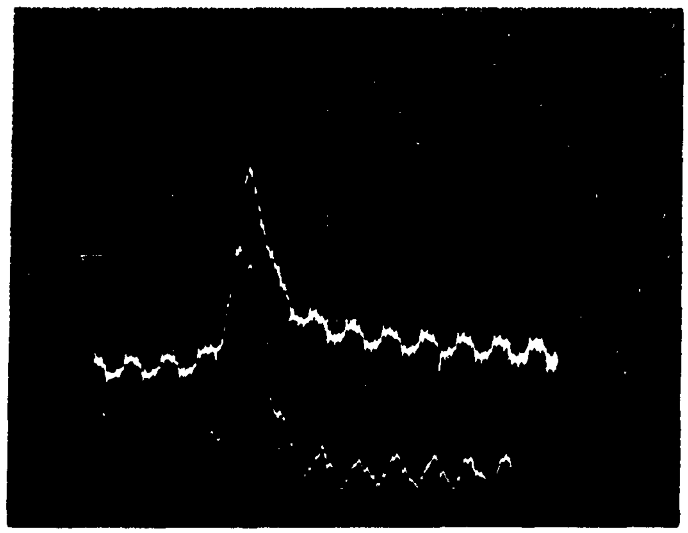
This was a successful shot, though with lower apogee than expected, owing to the vehicle being launched at an angle of attack with a resulting off-azimuth trajectory.

FABIUS

4 JUNE 1965 - 0317 HR AST

8,700 psi per cm (division)

BREECH PRESSURE



TIME

20 milliseconds per cm (division)

Maximum Breech Pressure: Pmax = 36,500 psi

Fig. 11 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND FABIUS

FABIUS

4 JUNE, 1965 0317 HR AST

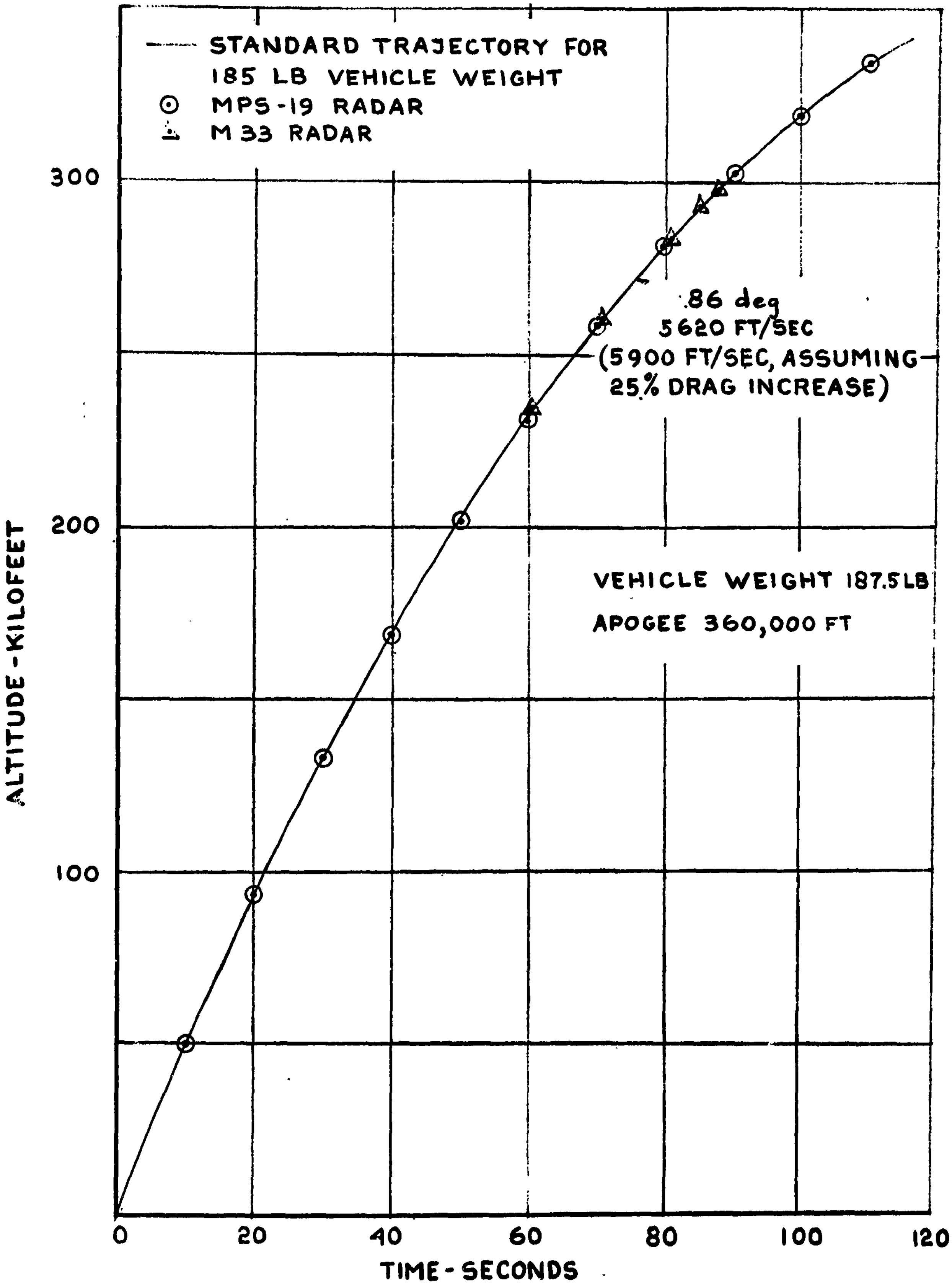


FIG. 11a MARTLET 2C SHOT FABIUS

ALTITUDE VS TIME

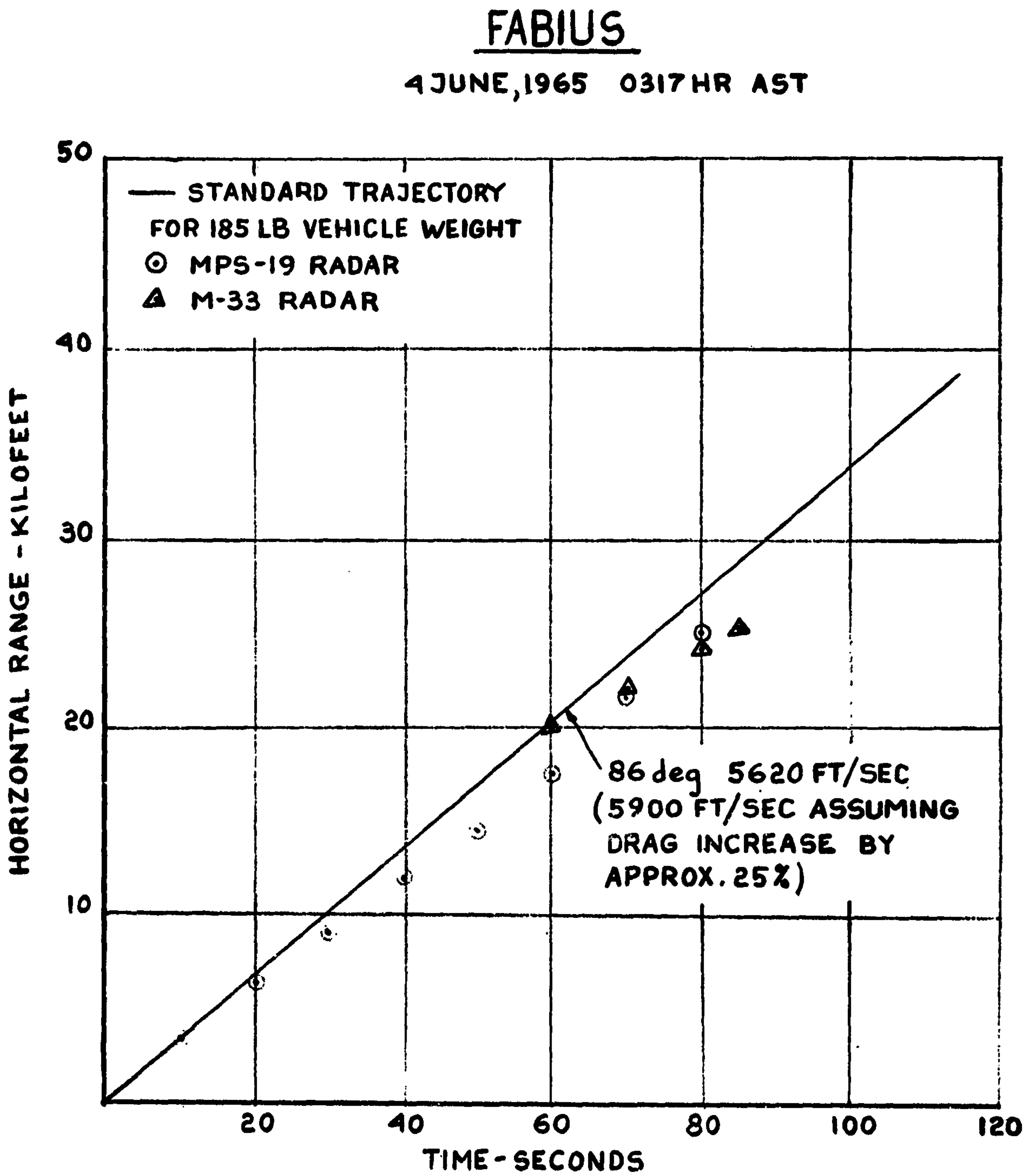


FIG. 11b MARTLET 2C SHOT FABIUS

RANGE VS TIME

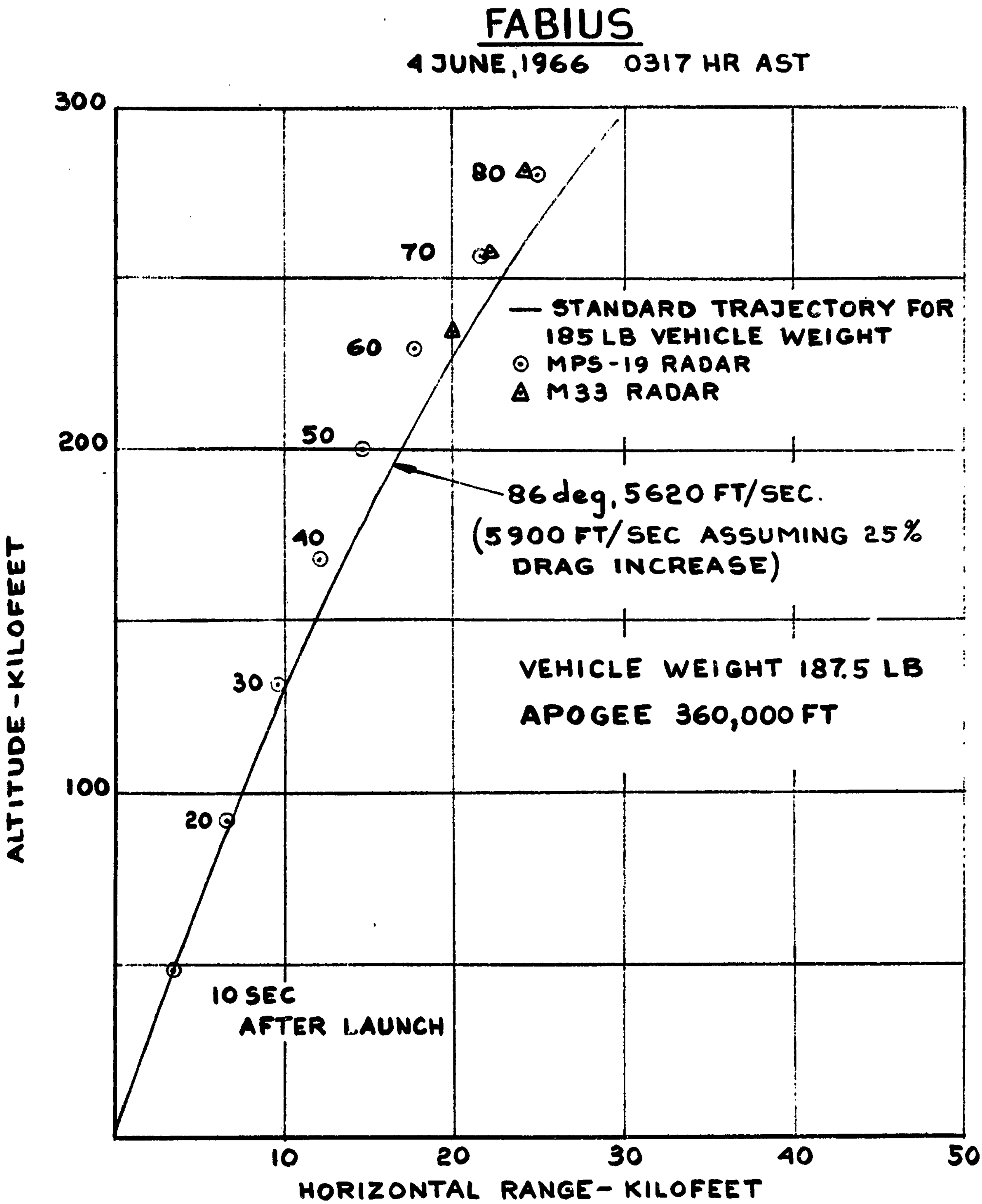


FIG. 11c. MARTLET 2C SHOT FABIUS
ALTITUDE VS RANGE

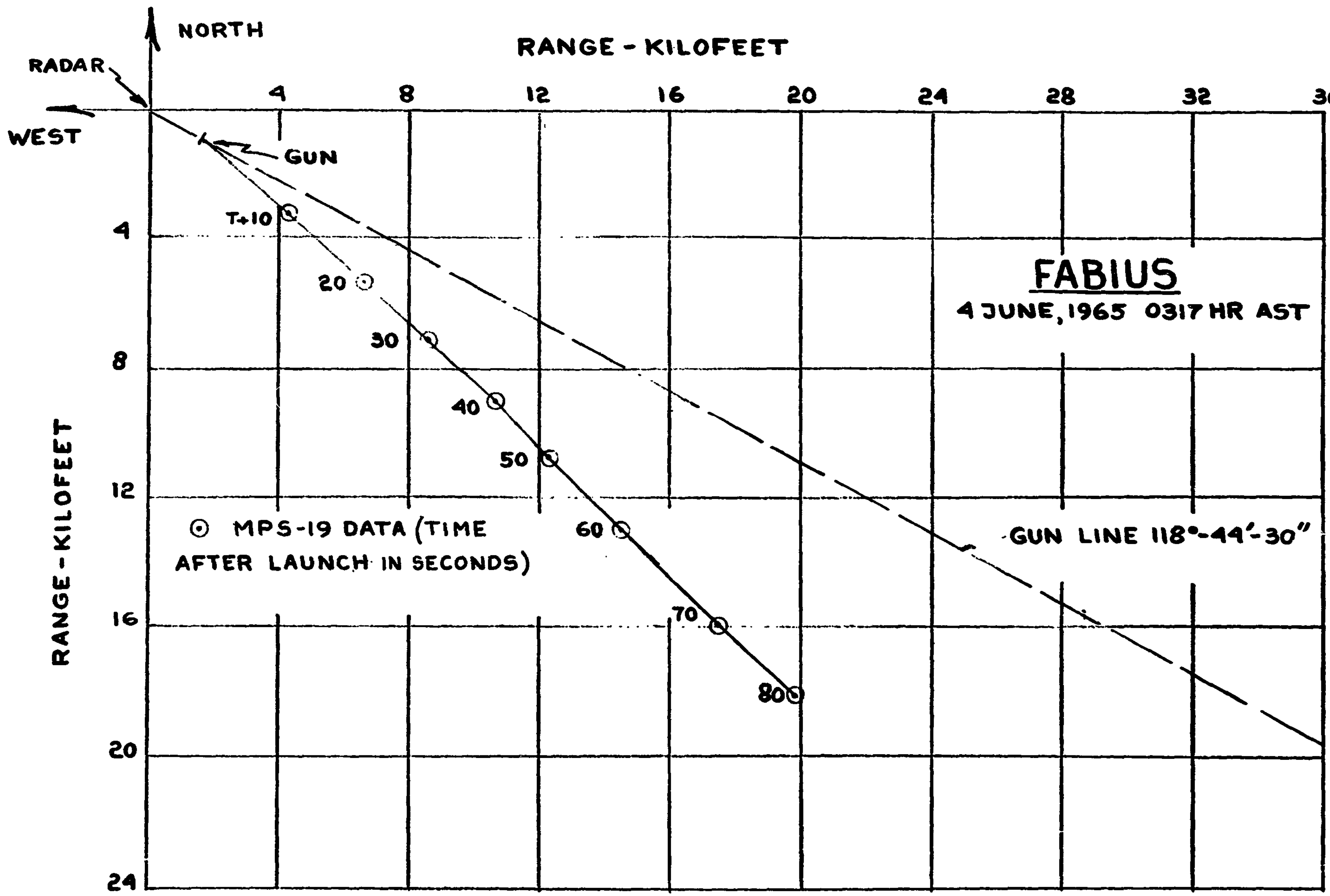


FIG. 11 d. PLAN VIEW OF MARTLET 2C FABIUS TRAJECTORY

4.5.5 Round No. 9 - GRACCHUS

Date: 5 June, 1965 - 1100 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb TMA to be ejected from T + 65 to T + 170 seconds.

Purpose of Test: Synoptic measurements of wind profiles.

Weights:	Vehicle	187.5 lb
	Pusher and Obturator	122.5 lb
	Sabot	105.0 lb
	Shot Weight	415.0 lb

Centre of Gravity: 22 in. from base.

Launch Data:

Charge Weight	750 lb M8M (8 bags)	
Swedish Additive	15 sheets	
Igniter	500 grams/bag	
Gun Elevation	82.5 degrees	
Crusher Gauges	M11 - 4	
Ram Distance	189 in	
Ram Load	25 tons	
Chamber Volume	40,160 in^3	
Recoil	37.5 in	
Breech Pressure	M11	38,300 psi
	Strain	36,500 psi (Fig. 12)
Muzzle Velocity Probe	left	6,460 ft/sec
	right	7,050 ft/sec

Camera Records:

Gracchus was fired in daylight as a vehicle engineering test. Good smear and Fastax photographs of launch were obtained. The evaluation of West Fastax photographs gave the following muzzle velocity value (6 in. lens, 160 ft ahead of muzzle): 5,810 ft/sec. East Fastax pictures showed the vehicle obscured in gas clouds, and no result could be obtained from the double smear camera.either.

Radar Records:

Both the M-33 and the MPS-19 radars tracked the flight to near apogee. An azimuth dispersion in the order of 3 to 4 deg was observed.

Trajectory:

Figs. 12a to 12d show the radar results in comparison with the standard trajectory for 5,750 ft/sec at 82.5 deg.

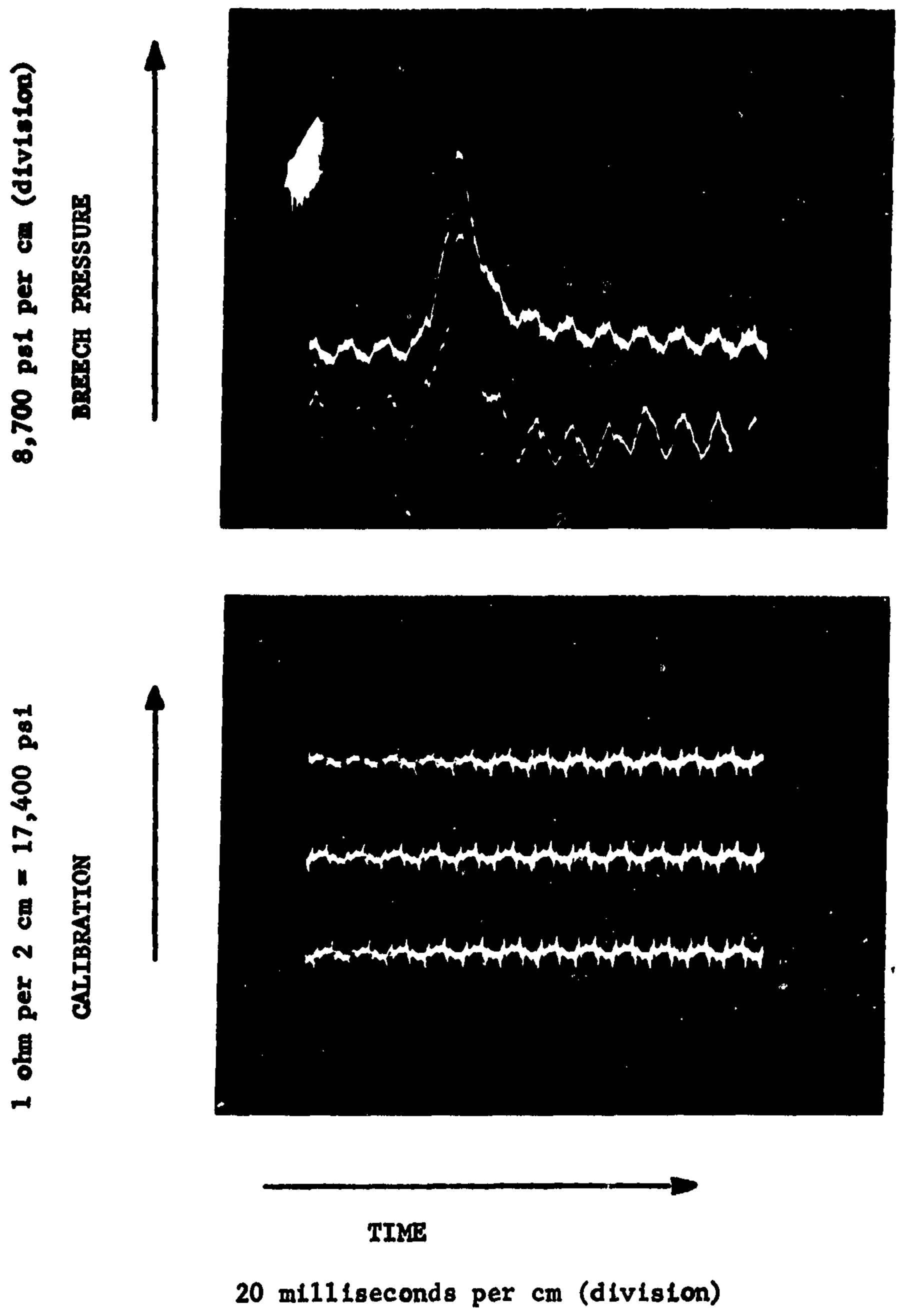
The apogee was 375,000 ft = 114 km, and the estimated total range 189,000 ft.

Summary:

Successful flight, with good camera results obtained.

GRACCHUS

5 JUNE 1965- 1100 HR AST



Maximum Breech Pressure: Pmax = 36,500 psi

Fig. 12 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND GRACCHUS

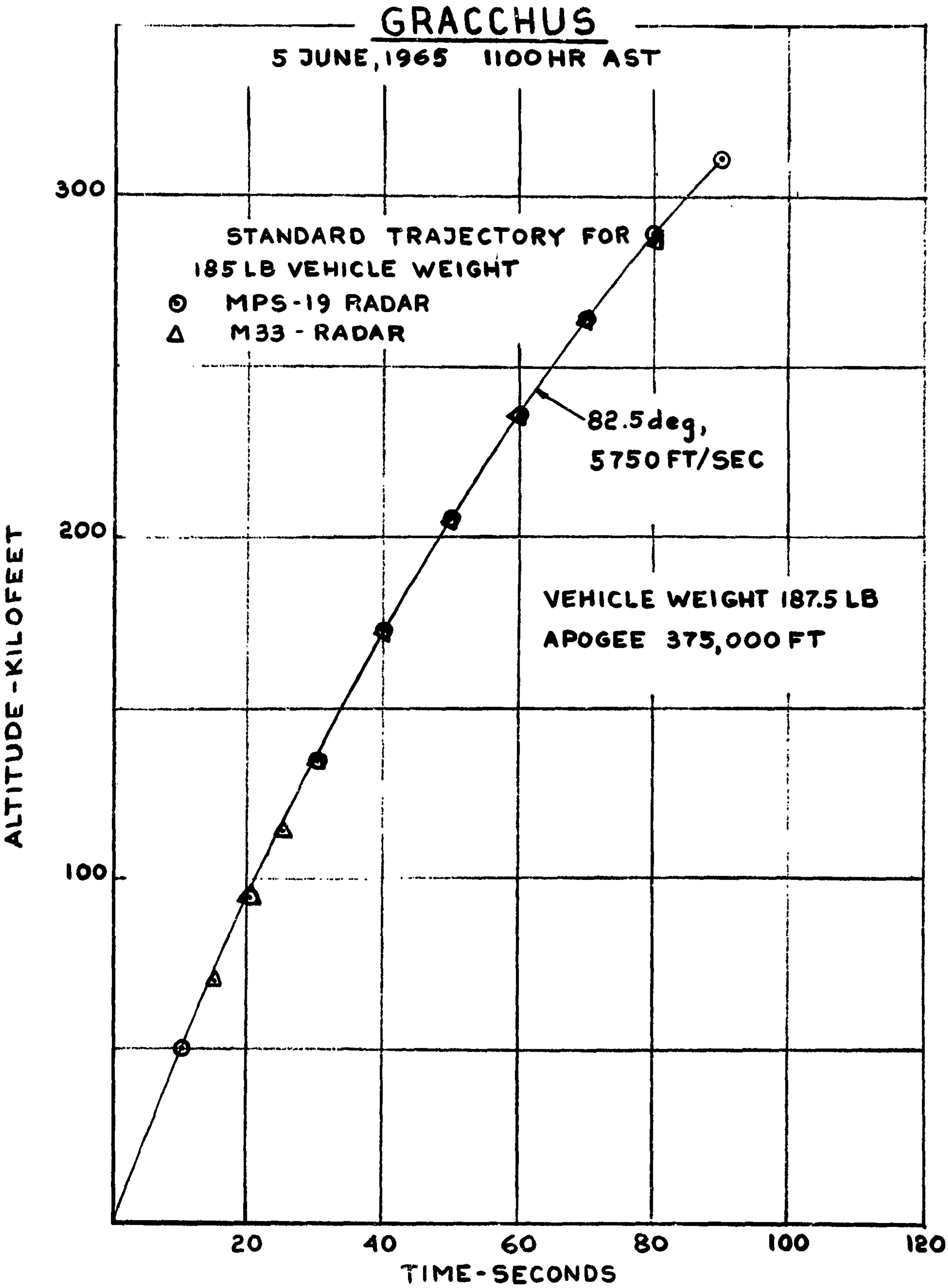


FIG. 12a MARTLET 2C SHOT GRACCUS
ALTITUDE VS TIME

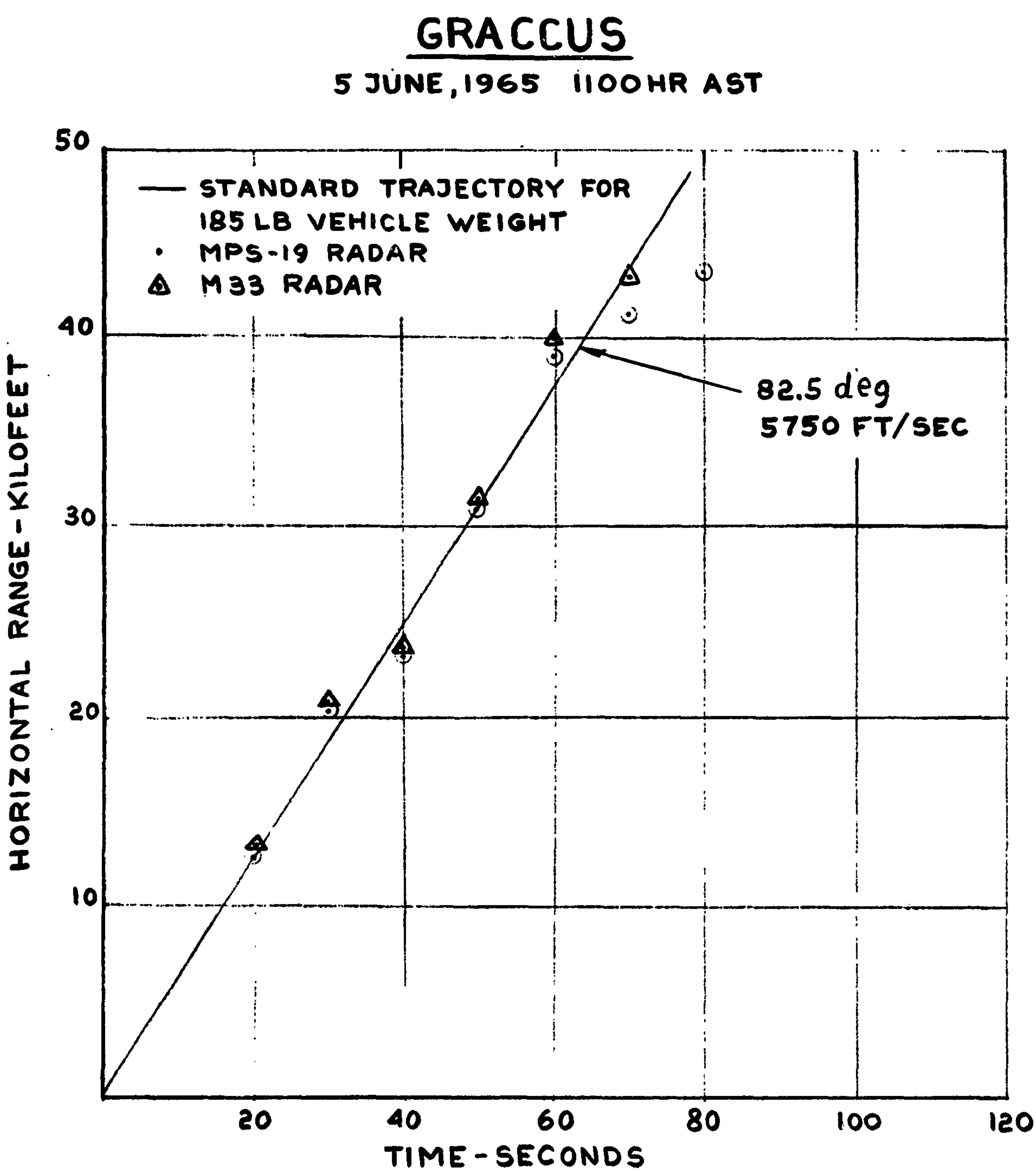


FIG. 12b MARTLET 2C SHOT GRACCHUS
RANGE VS TIME

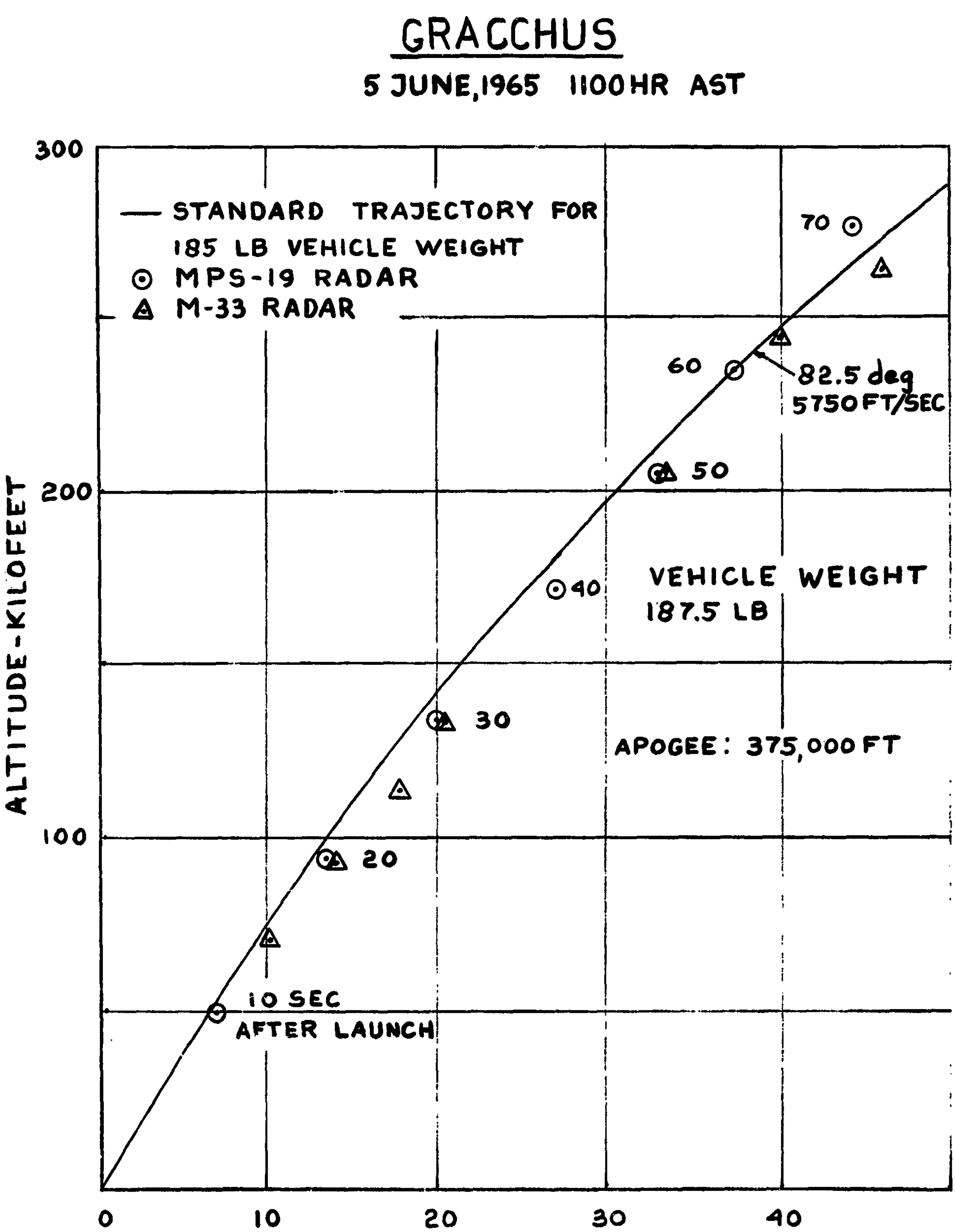


FIG. 12c MARTLET 2C SHOT GRACCHUS
ALTITUDE VS RANGE

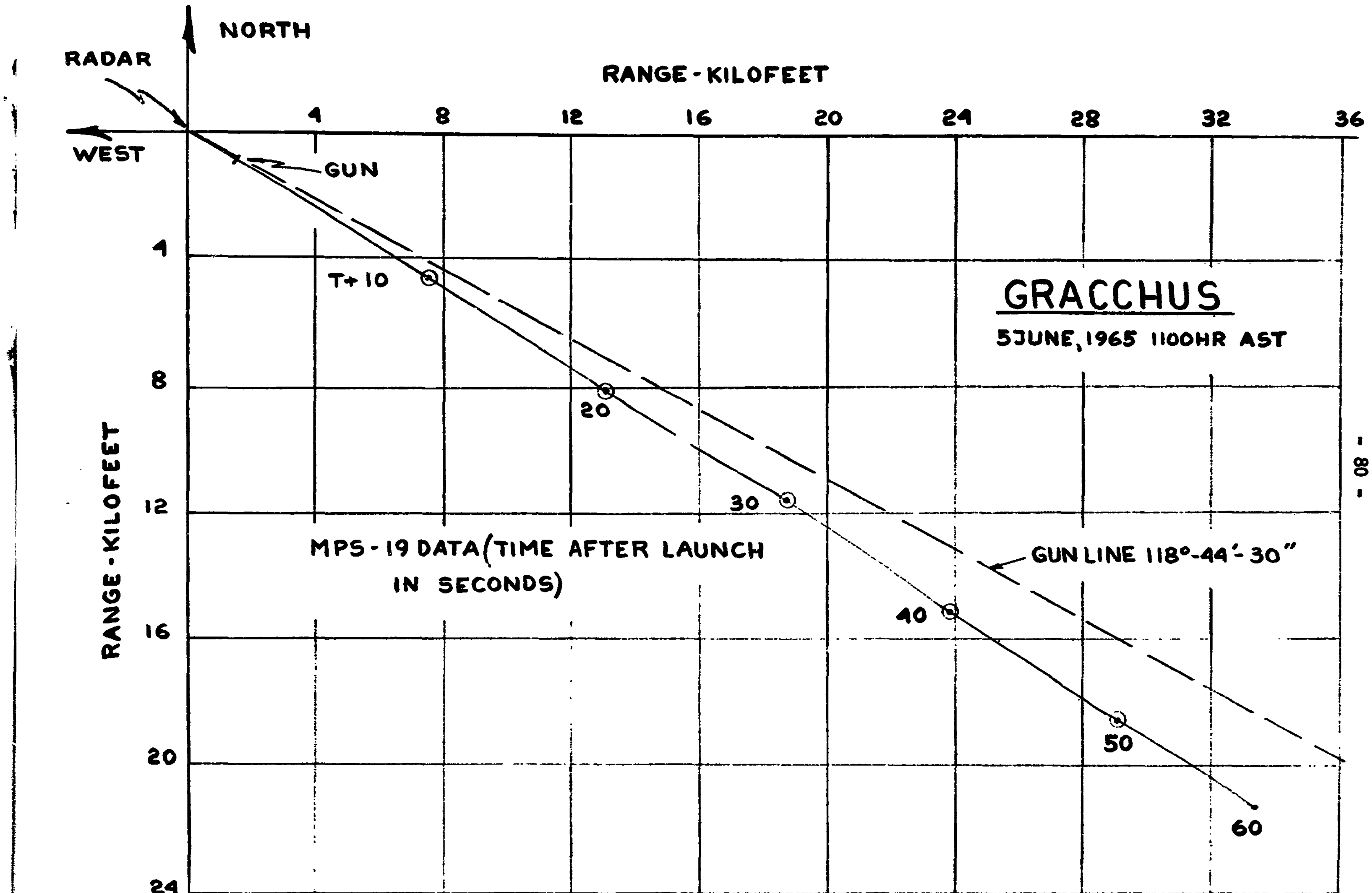


FIG.12d PLAN VIEW OF MARTLET 2C GRACCHUS TRAJECTORY

4.5.6 Round No. 14 - LUCRETIA

Date: 9 June, 1965 - 1851 hr A.S.T.

Vehicle Description: Martlet 2C carrying a 5.5 lb package of TMA and HDL 240 MHz telemetry with temperature gauges and magnetometer.

Purpose of Test: Synoptic measurements of wind profiles, and to demonstrate the feasibility of using flux-gate magnetometers on HARP vehicles.

Weights:		
	Vehicle	189.0 lb
	Pusher and Obturator	122.5 lb
	Sabot	103.5 lb
	Shot Weight	415.0 lb

Centre of Gravity: 21.8 in. from base.

Launch Data:

Charge Weight	750 lb M8M (8 bags)
Swedish Additive	18 sheets
Igniter	500 grams/bag
Gun Elevation	82.5 degrees
Crusher Gauges	M11 - 4
	Mk6 - 4
Ram Distance	190.6 in
Ram Load	15 tons
Chamber Volume	40,500 in^3
Recoil	37.5 in
Breech Pressure	M11 38,900 psi
	Mk6 38,000 psi
	Strain 36,500 psi (Fig. 13)
Muzzle Velocity Probe	left 6,060 ft/sec
	right 6,270 ft/sec

Note: The gun was evacuated.

Radar Records:

The MPS-19 radar tracked normally. M-33 obtained only the point coordinates at T + 70 sec.

Trajectory:

The radar data, shown in Fig. 13a to 13d, are plotted in comparison with a standard drag trajectory of 5,900 ft/sec at 82.5 deg launch elevation. The range data indicates that the effective launch angle was evidently smaller (81.5 deg).

The apogee was 388,000 ft = 118 km. The MPS-19 radar observed the impact at a range of 223,500 ft, at an azimuth of approximately 121 deg.

Telemetry:

Telemetry signals were received up to T + 10 seconds and then lost until T + 194 seconds. At this time telemetry signals were acquired again until 310 seconds after launch. The frequency remained constant at 242 MHz. There was some interference of a random nature over the entire band, probably caused by a high voltage transformer.

Both the magnetometer and the temperature gauge functioned. Spin and tumbling rates were obtained from the magnetometer data.

Vehicle Performance:

The magnetometer results indicated a spin rate of 13 rps after launch; after T + 194 seconds, when telemetry was again acquired, the spin rate was found to be steady at 12 rps.

At T + 270 seconds the vehicle started coning at ½ rps, increasing to 1 rps at T + 300 seconds.

TMA Trail Results:

All tracking stations were operational and some photographs were taken; no evaluation, however, was possible because of cloud coverage.

Summary:

Moderately successful shot in that the payload items worked properly, except for loss telemetry transmission for 124 sec. No wind data could be obtained because of weather conditions. The effect of gun evacuation on muzzle velocity was not evident.

LUCRETIA

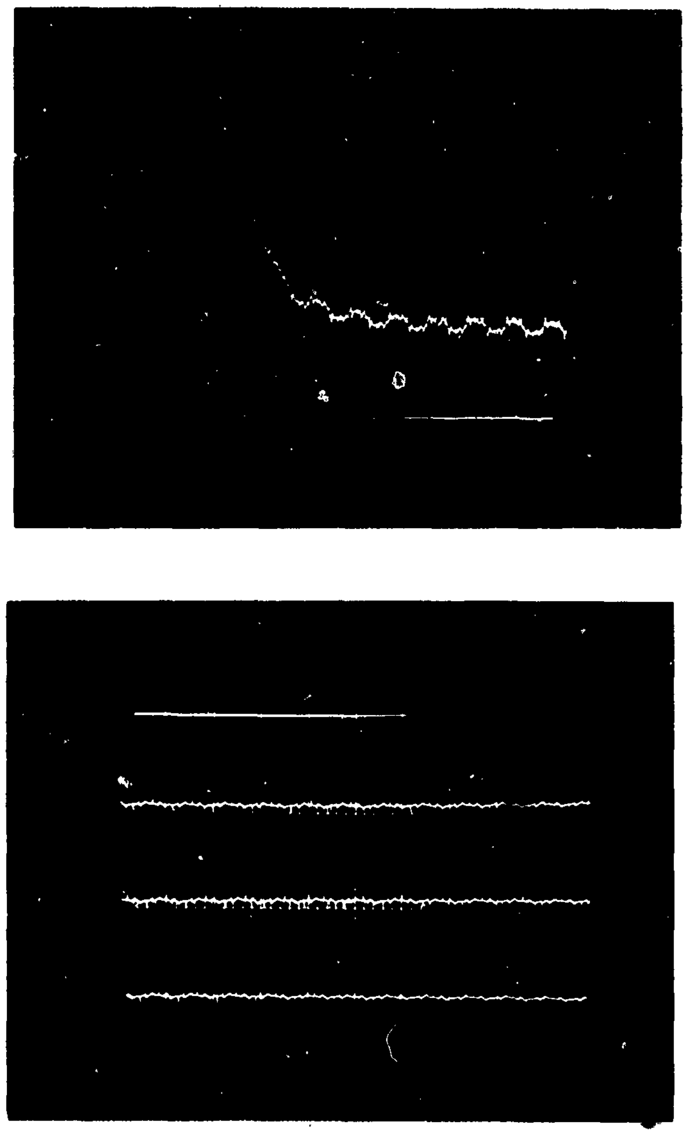
9 JUNE 1965 - 1851 HR AST

8,700 psi per cm (division)

BREECH PRESSURE

1 ohm per 2 cm = 17,400 psi

CALIBRATION



TIME

20 milliseconds per cm (division)

Maximum Breech Pressure: Pmax = 36,500 psi

Fig. 13 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND LUCRETIA

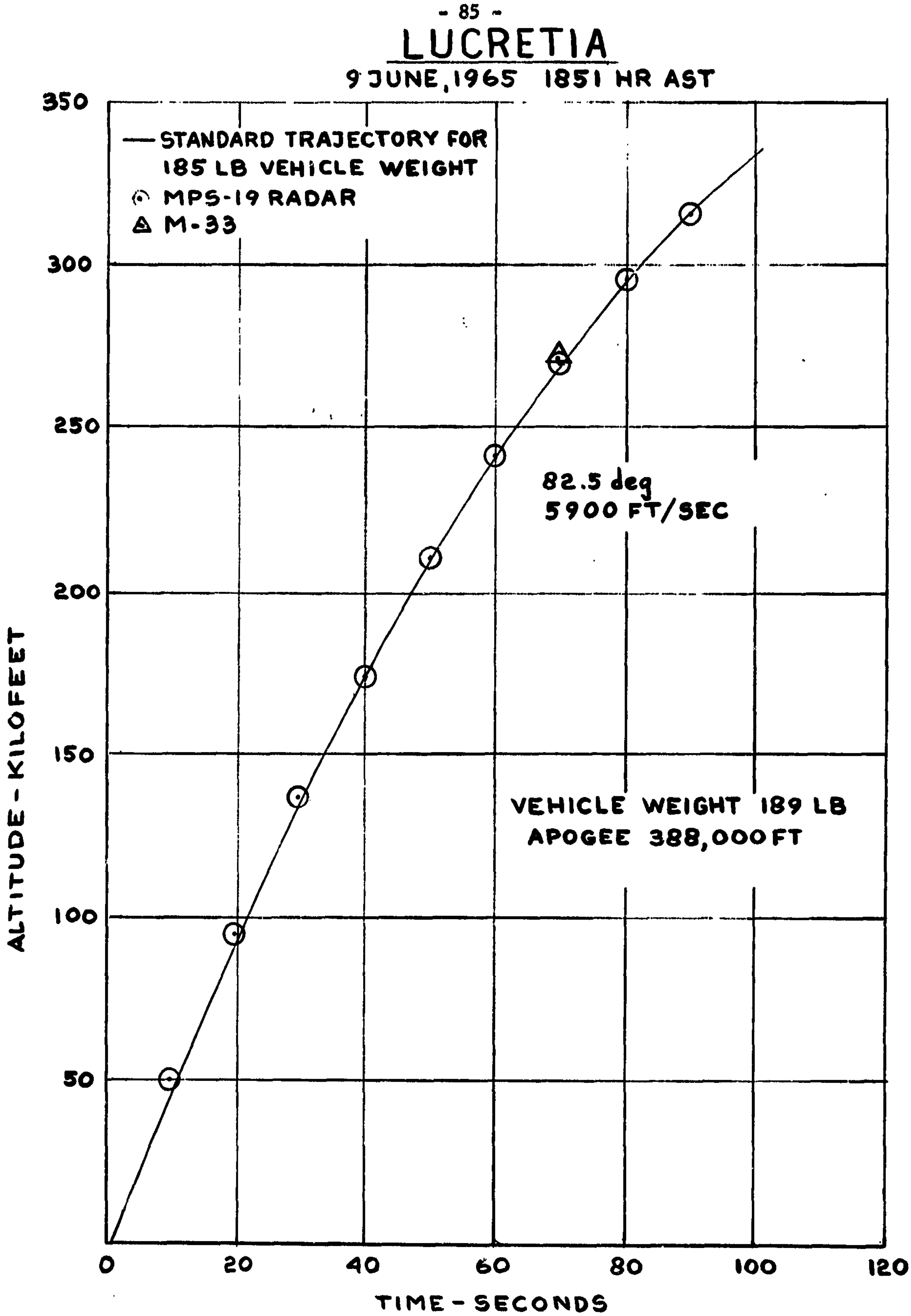


FIG. 13a MARTLET 2C SHOT LUCRETIA

ALTITUDE VS TIME

LUCRETIA

9 JUNE, 1965 1851 HR AST

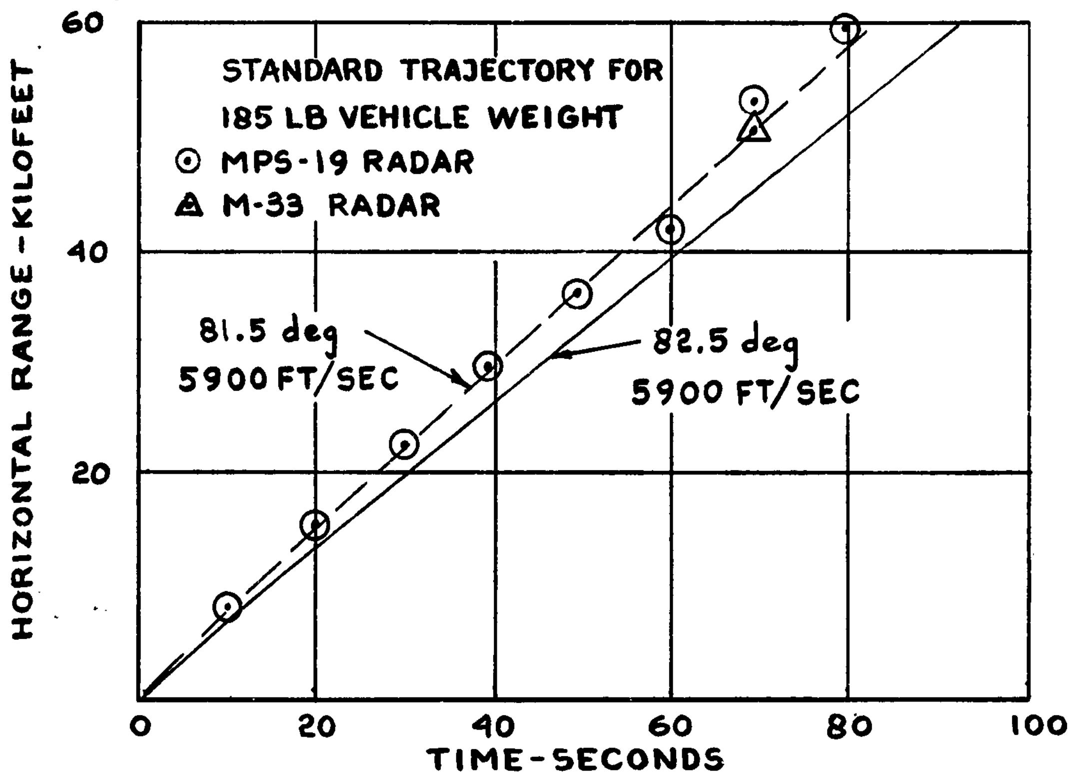


FIG.13b MARTLET 2C SHOT LUCRETIA

RANGE VS TIME

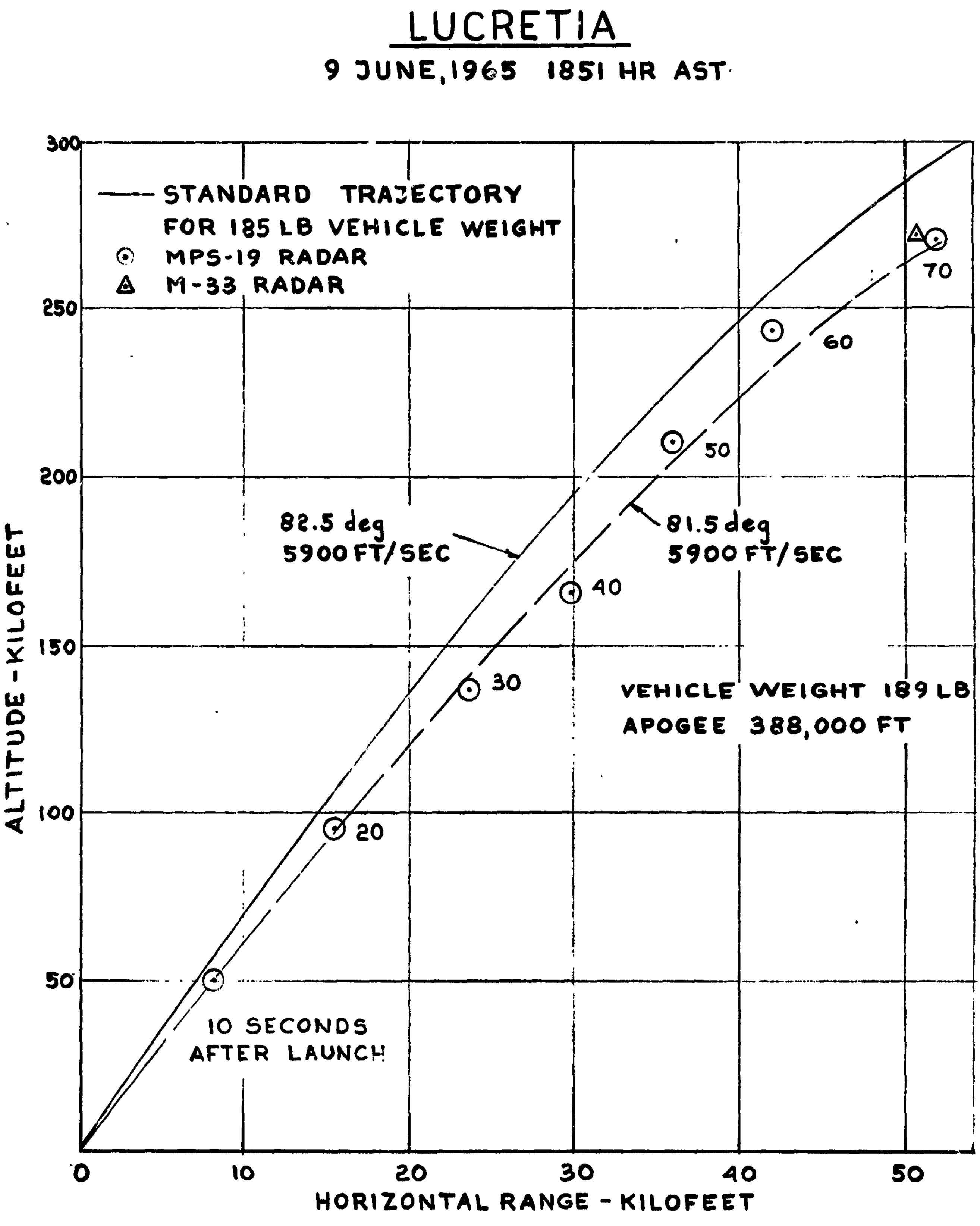


FIG. 13c MARTLET 2C SHOT LUCRETIA
ALTITUDE VS RANGE

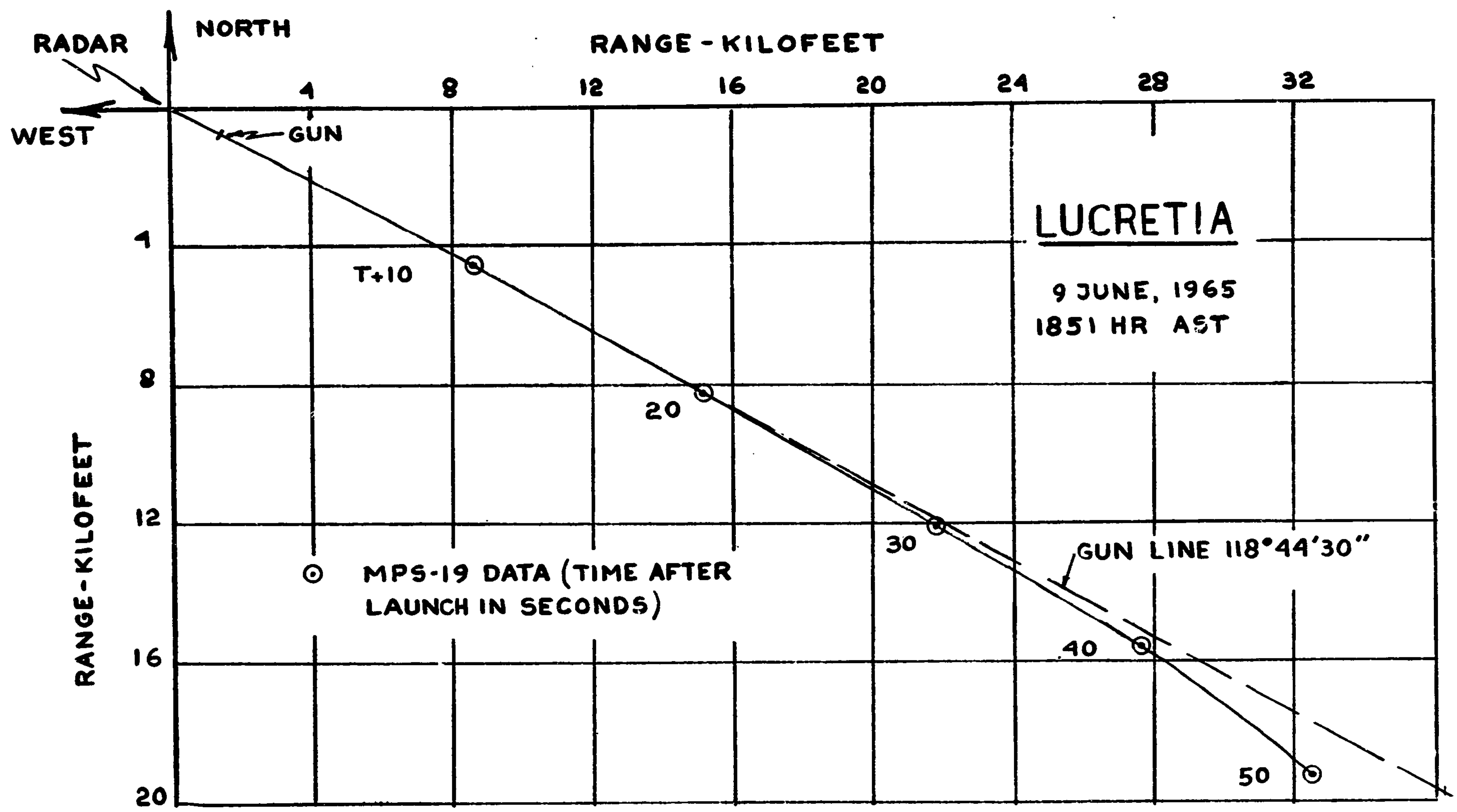


FIG.13d PLAN VIEW OF MARTLET 2C LUCRETIA TRAJECTORY

4.5.7 Round No. 15 - OVID

Date: 9 June, 1965 - 2157 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb TMA payload to be ejected from T + 65 to T + 170 seconds.

Purpose of Test: Synoptic measurements of wind profiles.

Weights:	Vehicle	188.0 lb
	Pusher and Obturator	122.0 lb
	Sabot	104.0 lb
	Shot Weight	414.0 lb

Centre of Gravity: 22.0 in. from base.

Launch Data:

Charge Weight	750 lb M8M (8 bags)	
Swedish Additive	18 sheets	
Igniter	500 grams/bag	
Gun Elevation	82.5 degrees	
Crusher Gauges	M11 - 4	
	Mk6 - 4	
Ram Distance	192 in	
Ram Load	25 tons	
Chamber Volume	40,800 in^3	
Recoil	38 in	
Breech Pressure	M11	38,900 psi
	Mk6	36,900 psi
	Strain	34,800 psi (Fig. 14)
Muzzle Velocity Probe	left	6,080 ft/sec
	right	6,150 ft/sec

Radar Records:

Both the M-33 and MPS-19 radar tracked the vehicle to approximately 280,000 ft. The MPS-19 radar was also on target at T + 296 sec, shortly before splash-down. A horizontal range of 189,000 ft at an altitude of 30,000 ft was measured.

Trajectory:

The radar data are in agreement with the standard trajectory for 5,500 ft/sec, with the range data indicating a launch angle of about 81.5 deg instead of 82.5 deg as recorded (Fig. 14a-14d). A velocity of 5,500 ft/sec, however, appears to be small in relation to the charge weight and the recorded pressure. Therefore it must be assumed that the actual muzzle velocity was higher as also shown by the muzzle probe data which are in the order of 6,100 ft/sec. If this latter value is correct a drag increase of 45% over the standard value would be indicated.

Fig. 14d shows the plan view of the trajectory indicating a small deviation from the gun line to the East.

The apogee of 341,000 ft = 105 kilometers as determined from the radar data, compares well with that obtained from the evaluation of the trail photographs (apogee = 103 kilometers).

The estimated range was 192,400 ft which compared well with the measured range 189,000 ft at an altitude of 30,000 ft.

TMA Trail Results:

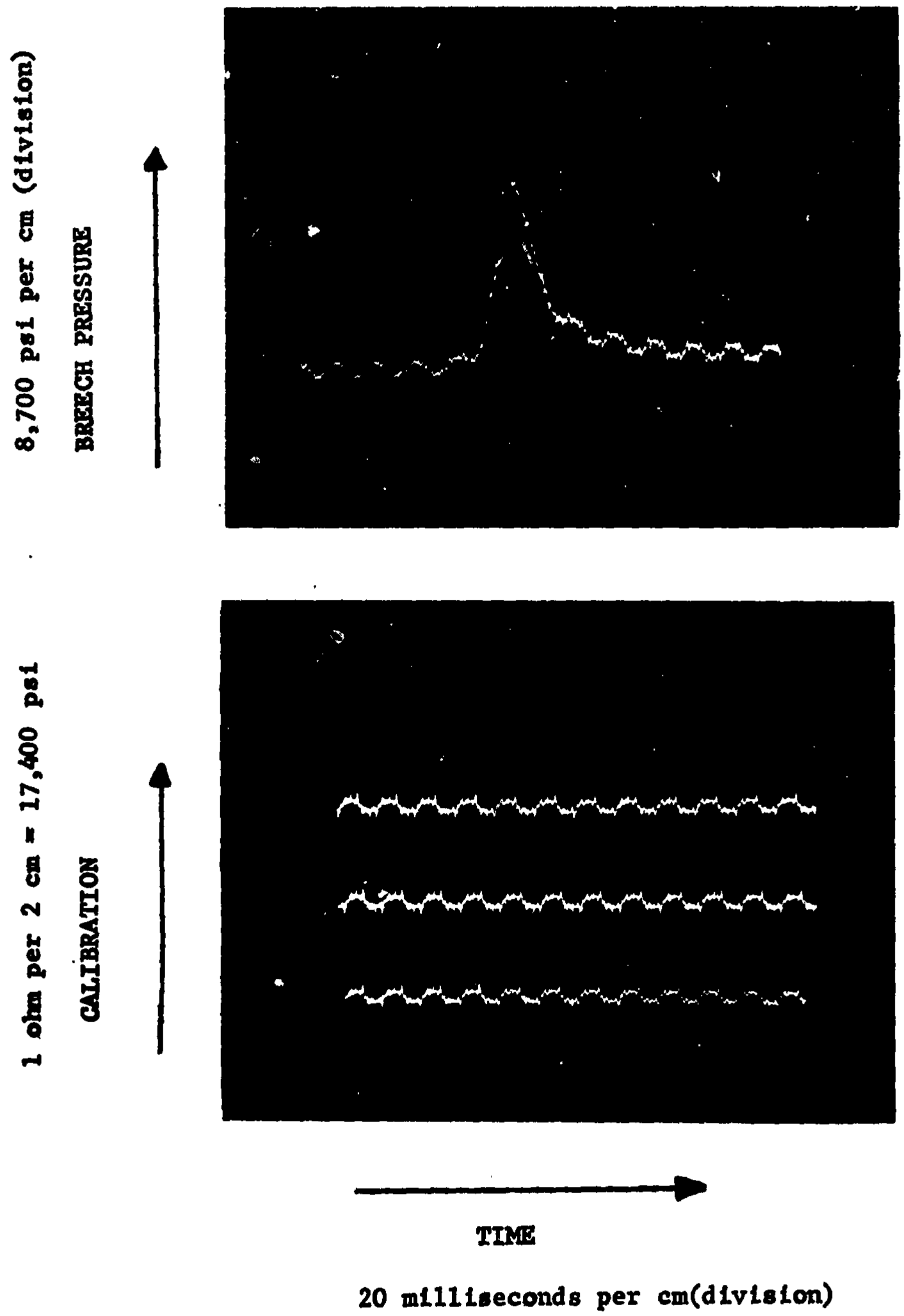
Cameras and payload performed satisfactorily. Wind shear data were obtained from 95 to 103 kilometers.

Summary:

Successful round.

OVID

9 JUNE 1965 - 2157 HR AST



Maximum Breech Pressure: Pmax = 34,800 psi

Fig. 14 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND OVID

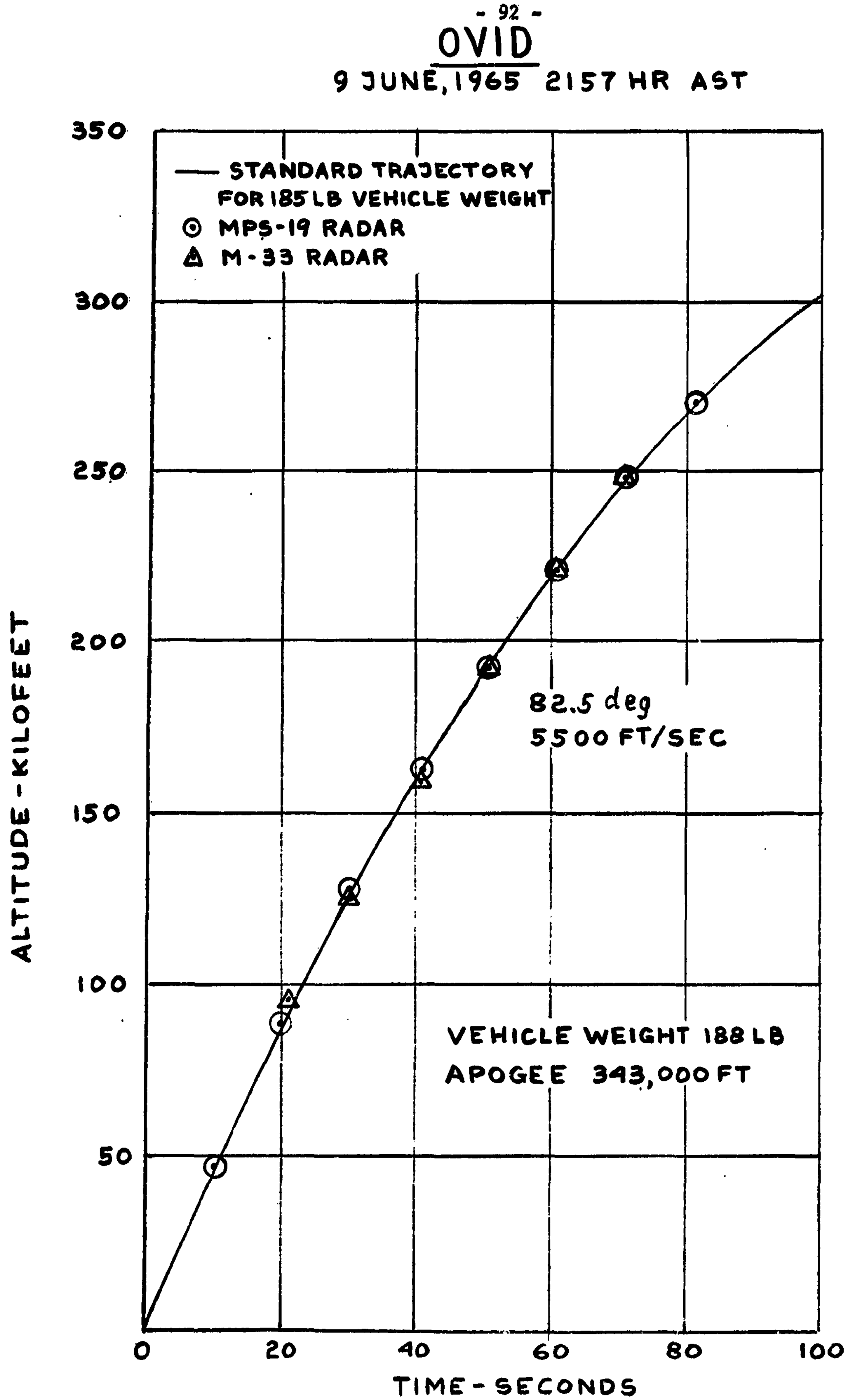


FIG. 14a MARTLET 2C SHOT OVID

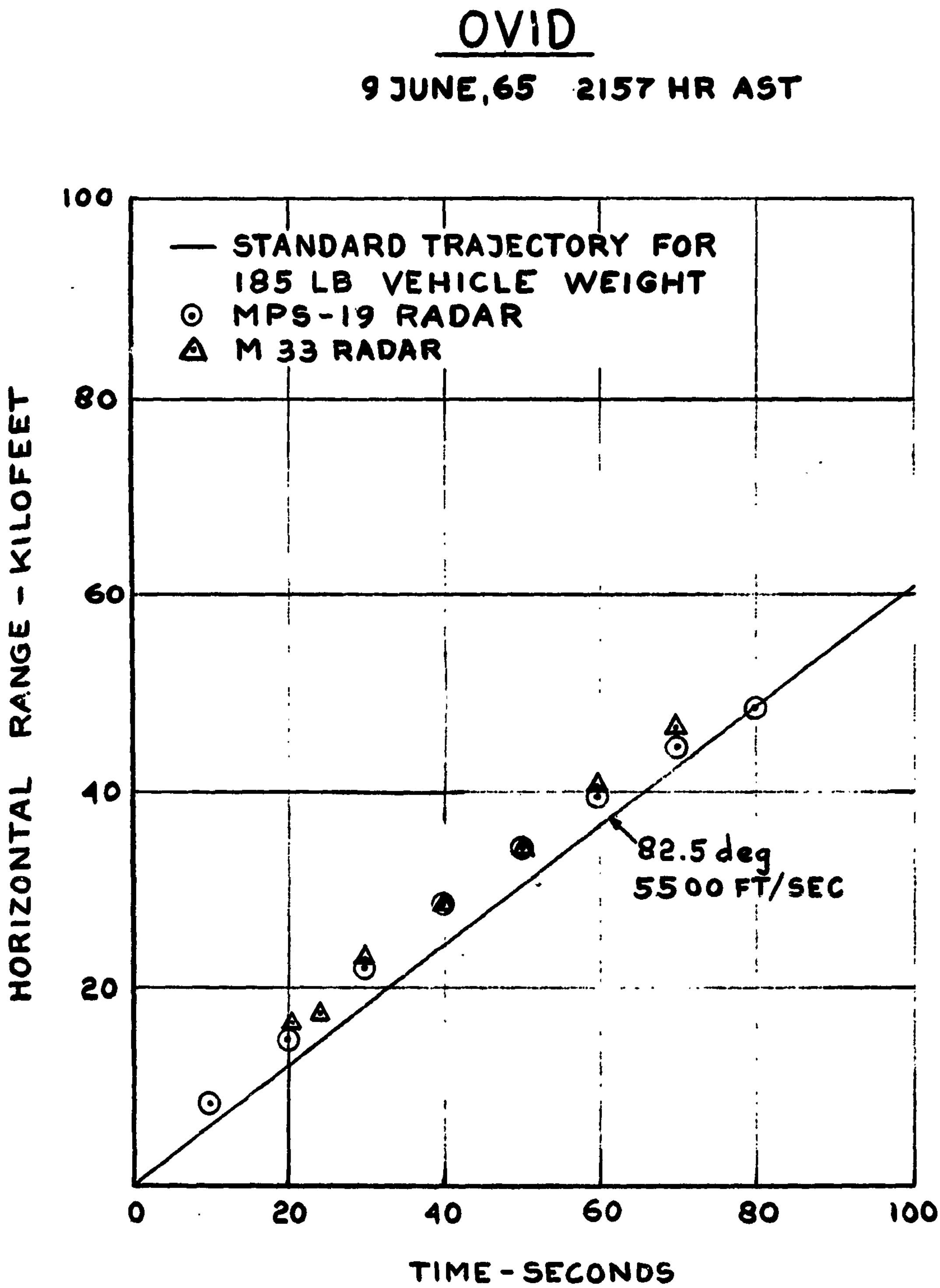


FIG. 14b MARTLET 2C SHOT OVID

RANGE VS TIME

OVID

9 JUNE, 1965 2157 HR AST

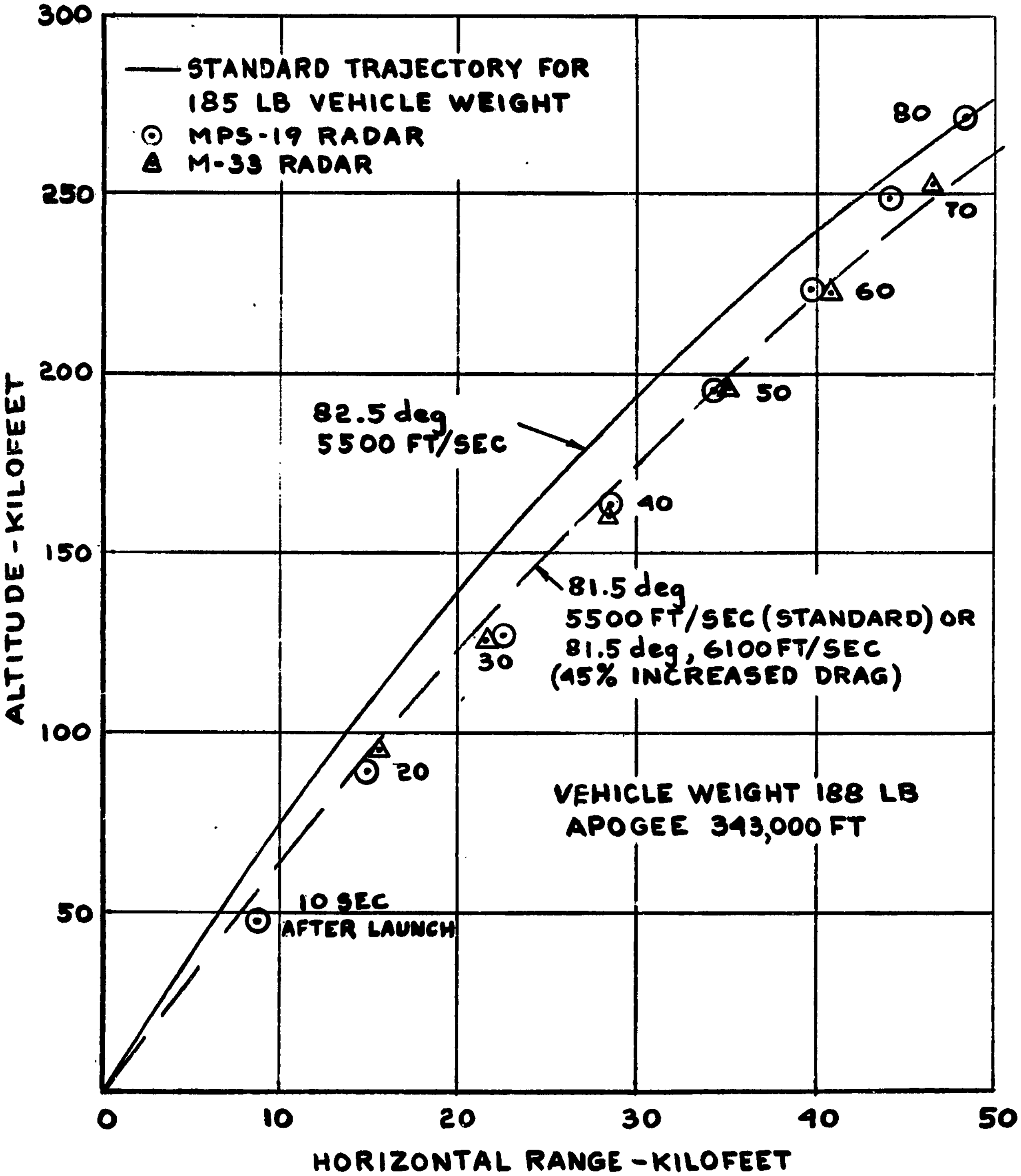


FIG.14c MARTLET 2C SHOT OVID

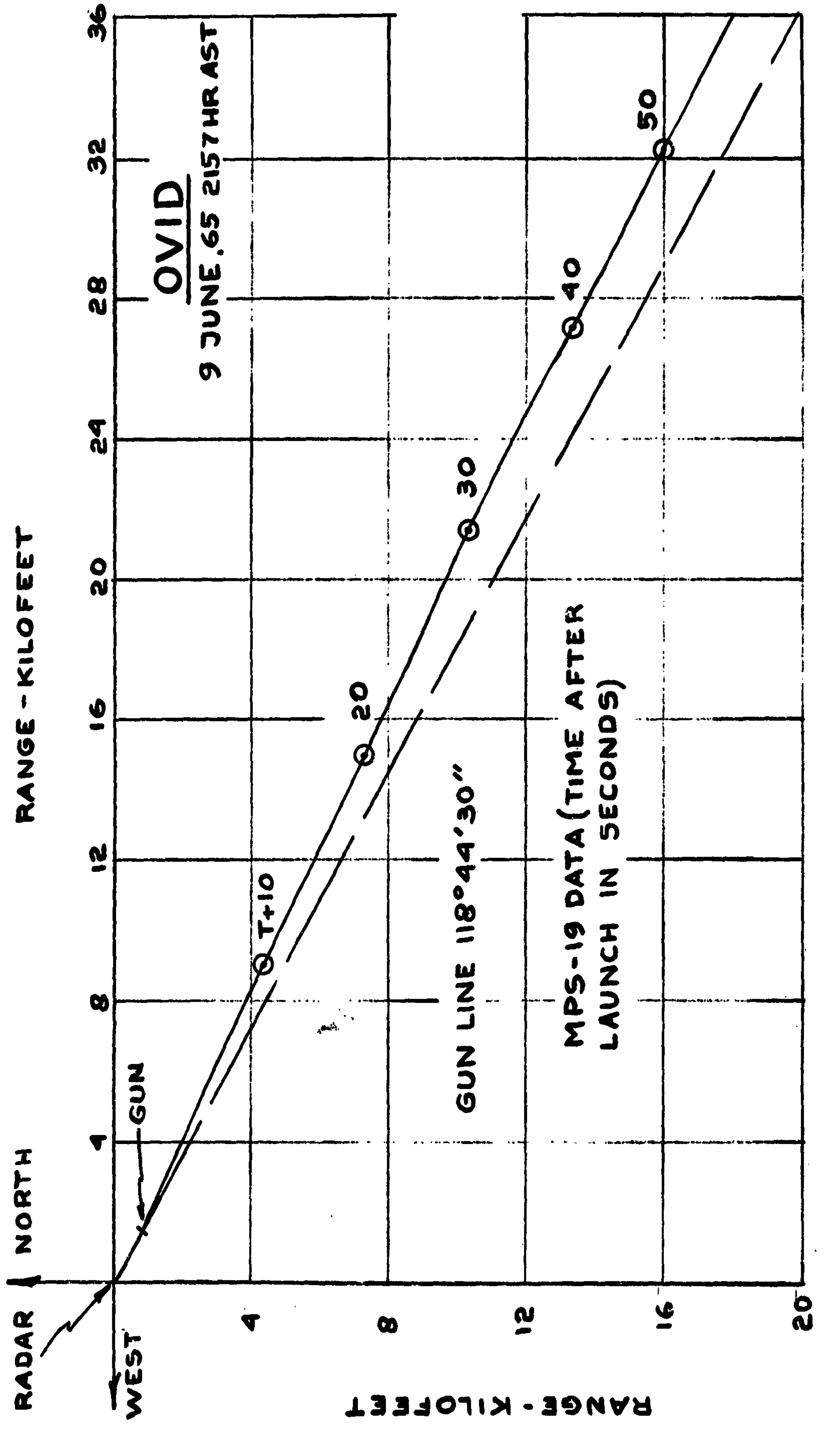


FIG.14J PLAN VIEW OF MARTLET 2C OVID TRAJECTORY

4.5.8 Round No. 16 - CICERO

Date: 9 June, 1965 - 2357 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb of TMA and 243 MHz HDL telemetry. TMA to be ejected at T + 65 sec. Telemetry to commence transmitting at T + 0.

Purpose of Test: Synoptic measurements of wind profiles, and to demonstrate the feasibility of using flux-gate magnetometers on HARP vehicles.

Weights:	Vehicle	189.5 lb
	Pusher and Obturator	122.0 lb
	Sabot	106.0 lb
	Shot Weight	417.5 lb

Centre of Gravity: 21.8 in. from base.

Launch Data:

Charge Weight	760 lb M8M (8 bags)
Swedish Additive	18 sheets
Igniter	500 grams/bag
Gun Elevation	82.5 degrees
Crusher Gauges	M11 - 4
Ram Distance	192 in
Ram Load	17 tons
Chamber Volume	40,795 in^3
Recoil	38.5 in
Breech Pressure	M11 39,800 psi
	Strain 35,200 psi (Fig. 15)
Muzzle Velocity Probe	left 5,930 ft/sec
	right 5,970 ft/sec

Radar Records:

Both radars tracked normally.

Trajectory:

The radar data compared well with a standard drag trajectory for 5,600 ft/sec at 82.5 deg (Fig. 15a to c). An azimuth deviation

of approximately 5 deg was noted.

A muzzle velocity of 5,600 ft/sec appears small; apparently the drag was higher than standard. For 6,000 ft/sec muzzle velocity a drag increase of approximately 25% must be assumed.

The apogee was found to be 351,000 ft = 107 kilometers. St. Vincent and Tobago stations reported 100 and 107 kilometers respectively as obtained from phototheodolite data. The maximum range was measured as 183,000 ft by the MPS-19 radar.

Telemetry Records:

No tracking was obtained before apogee.

Telemetry was acquired at T + 211 seconds at 231 MHz, and received until 309 sec after launch, shortly before impact. Both the magnetometer and the temperature gauge worked.

Vehicle Performance:

In a similar fashion as for LUCRETIA, the vehicle began to cone with 0.3 rps at T + 252 sec. This rate increased to 1 rps at T + 279 sec. Simultaneously the spin rate which was 9 rps at T + 211 sec was reduced to 6.5 rps at T + 279 sec.

TMA Trail Results:

Cameras and payload performed satisfactorily. Wind shear data were obtained from 91 to 103 kilometers.

Summary:

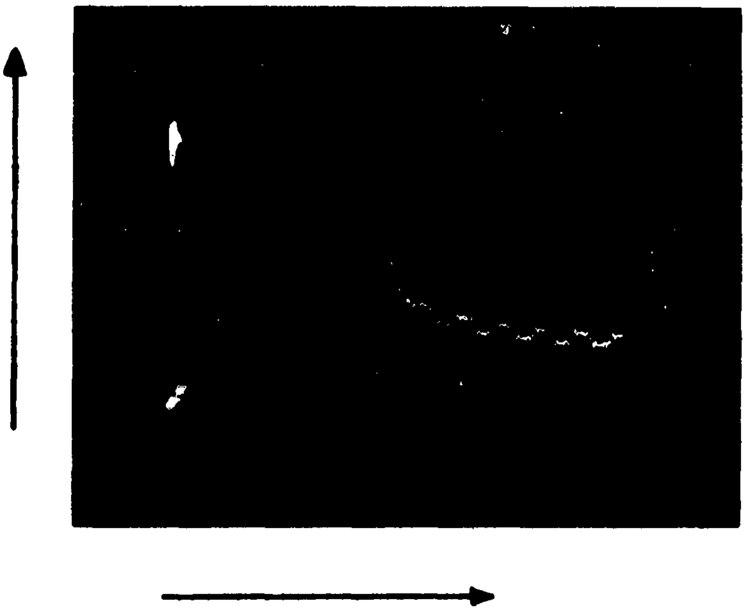
A moderately successful shot which achieved a good trajectory. TMA release, magnetometer, and temperature gauge worked properly. Telemetry did not function for 211 sec.

CICERO

9 JUNE 1965 - 2357 HR AST

8,700 psi per cm (division)

BREECH PRESSURE



TIME

20 milliseconds per cm (division)

Maximum Breech Pressure: Pmax = 35,200 psi

Fig. 15 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND CICERO

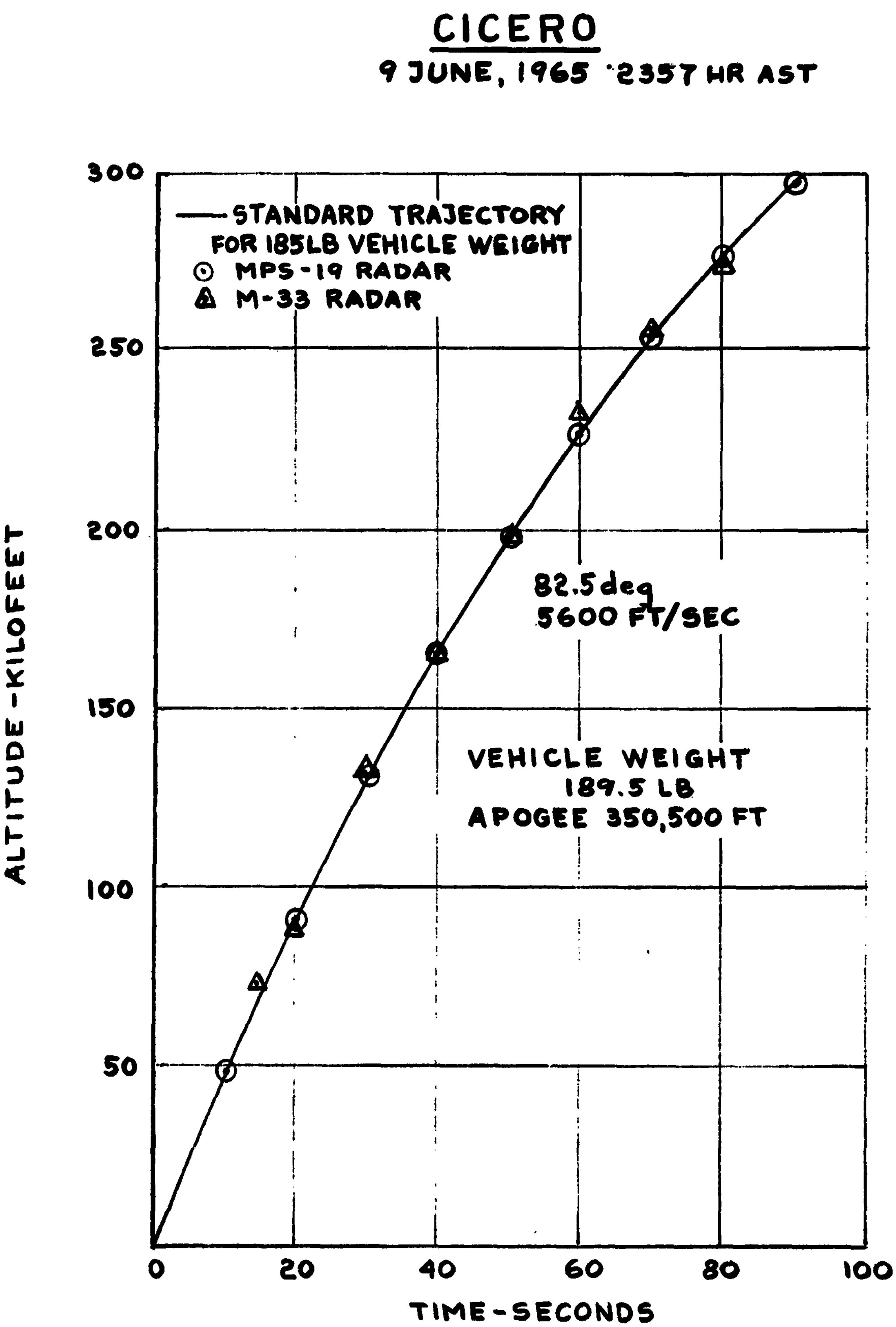


FIG. 15a MARTLET 2C SHOT CICERO
ALTITUDE VS TIME

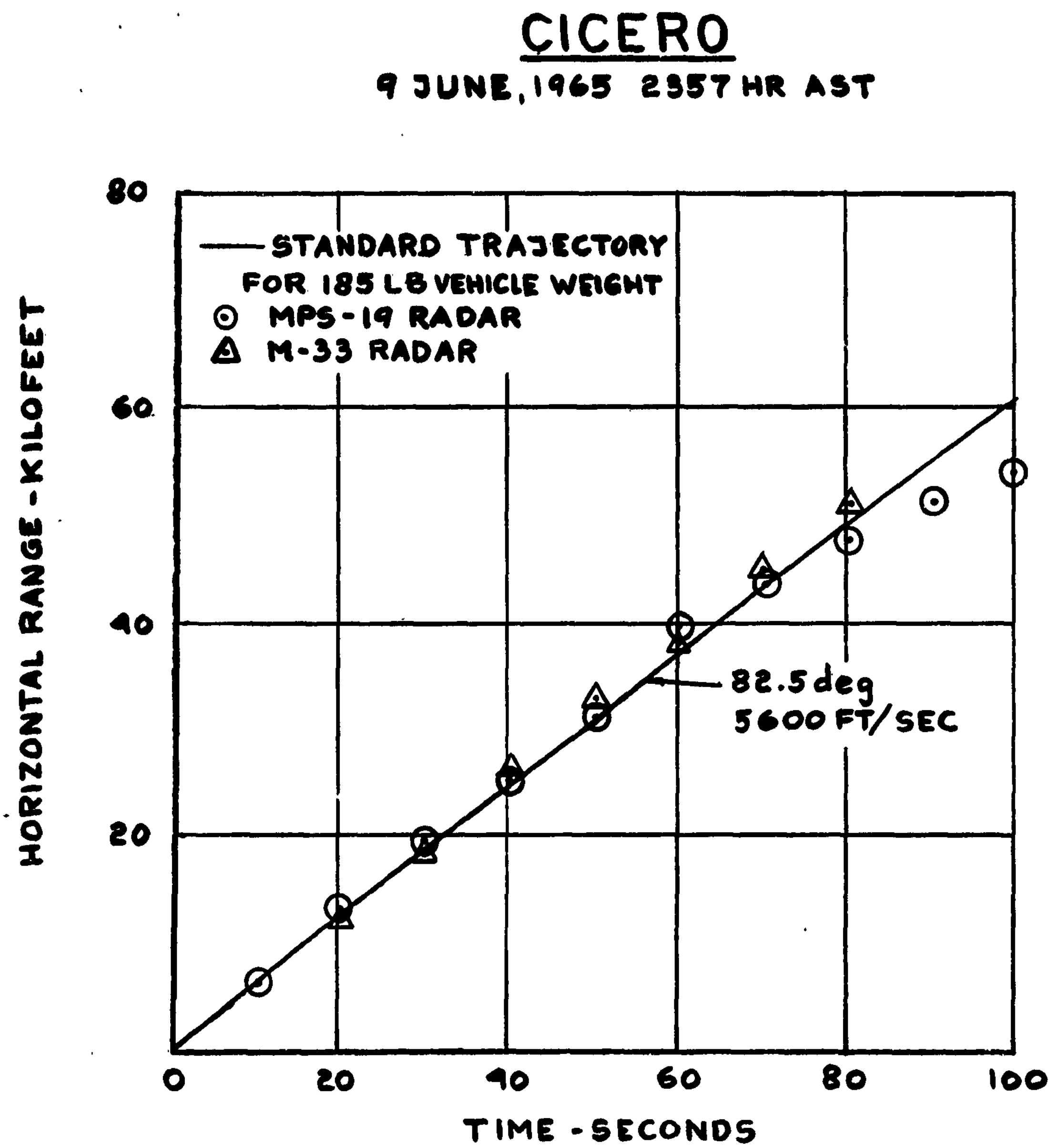


FIG. 15b MARTLET 2C SHOT

RANGE VS TIME

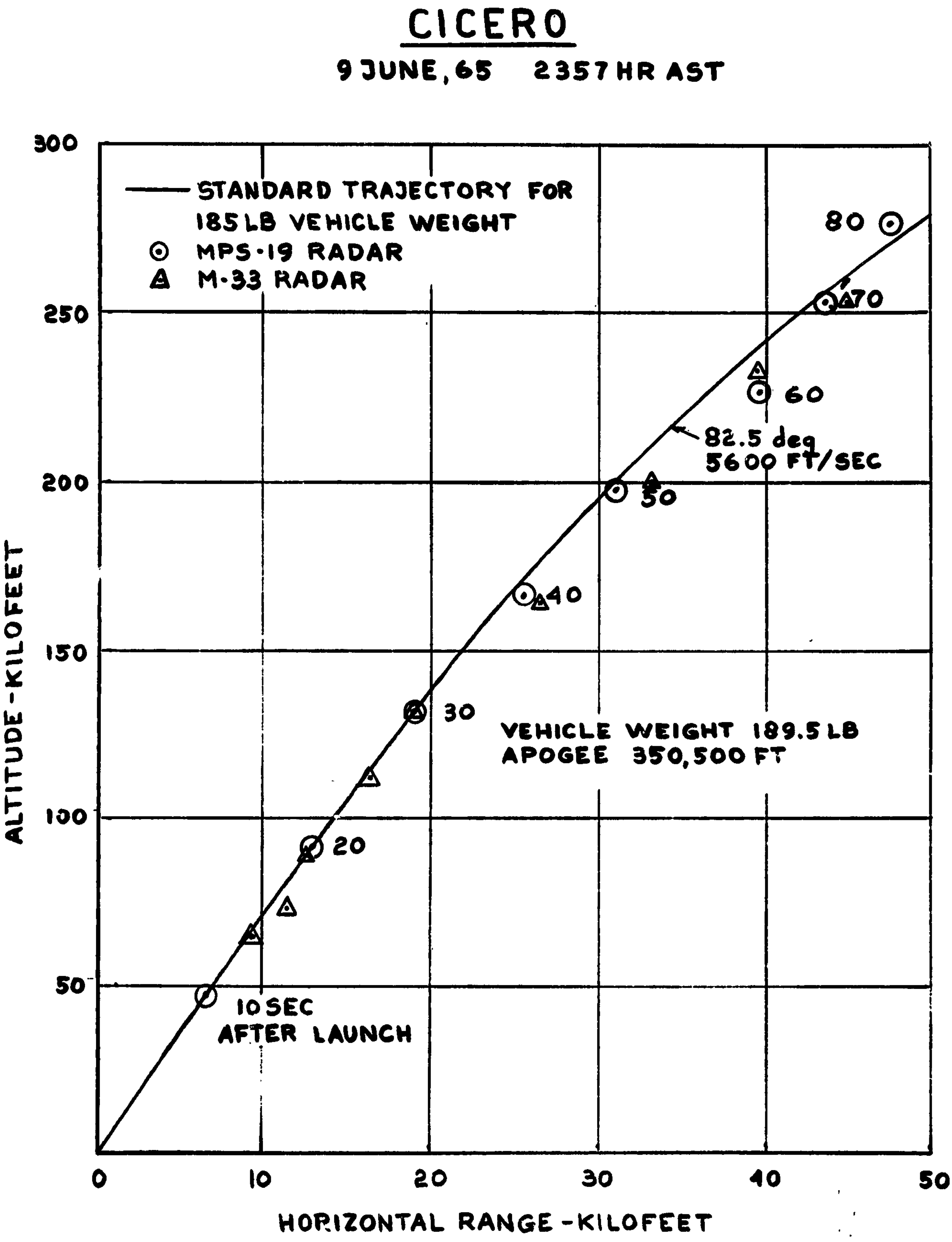


FIG.15c MARTLET 2C SHOT CICERO

ALTITUDE VS RANGE

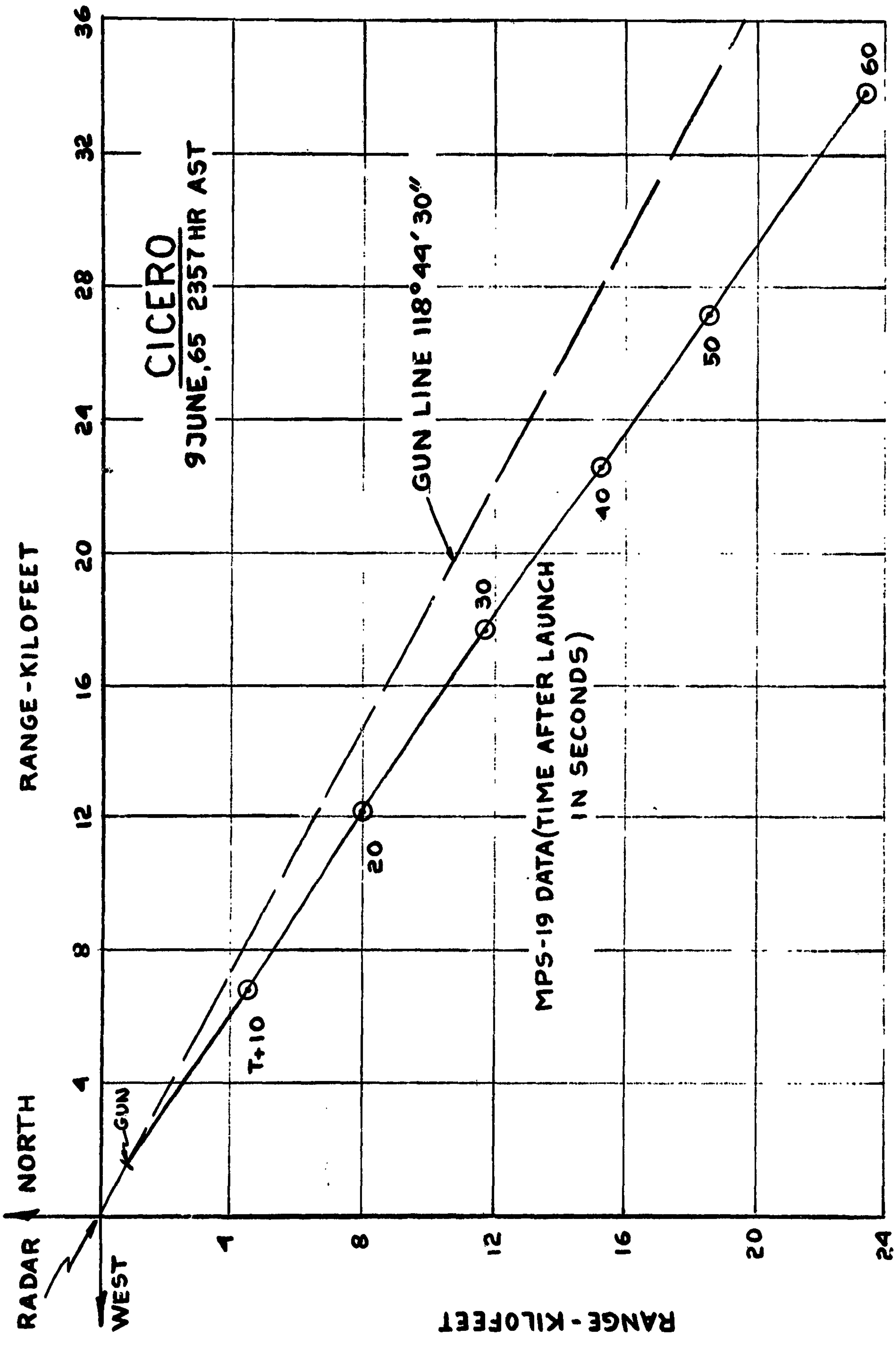


FIG. 15 d PLAN VIEW OF MARTLET 2C CICERO TRAJECTORY

4.5.9 Round No. 17 - DIANA

Date: 10 June, 1965 - 1235 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb TMA and HDL 247 MHz telemetry. TMA to be ejected at T + 65 sec. Telemetry to commence transmitting at T + 0.

Purpose of Test: Synoptic measurements of wind profiles, and to demonstrate the feasibility of using flux-gate magnetometers on HARP vehicles.

Weights:	Vehicle	189.0 lb
	Pusher and Obturator	122.0 lb
	Sabot	105.5 lb
	Shot Weight	416.5 lb

Centre of Gravity: 21.8 in. from base.

Launch Data:

Charge Weight	780 lb MSM (8 bags)
Swedish Additive	18 sheets
Igniter	500 grams/bag
Gun Elevation	82.5 degrees
Crusher Gauges	M11 - 4
Ram Distance	192.0 in
Ram Load	20 tons
Chamber Volume	40,800 in^3
Recoil	39 in
Breech Pressure	M11 46,300 psi Strain 43,200 psi (Fig. 16)
Muzzle Velocity Probe	left 5,170 ft/sec right 5,910 ft/sec

Radar Records:

Both radars tracked normally.

Trajectory:

Figs. 16a to 16c show the radar data in comparison with the standard drag trajectory for 5,700 ft/sec and 82.5 deg. The range data indicate again that the effective launch angle was re-

duced by 0.5 to 1 deg. A strong deviation from the gun line azimuth is apparent in Fig. 16d, pointing to the likelihood of launch at an angle of attack, high vehicle drag, and consequently the necessity for assuming a greater muzzle velocity.

The apogee was about 360,000 ft = 110 kilometers. The estimated range for this shot is 197,000 ft.

Telemetry Records:

Weak signals were picked up intermittently from 49 to 86 sec after launch at 231 MHz. Apparently the vehicle had lost its antenna. Note that in the case of LUCRETIA and CICERO, signal strength was high near splash-down. In the present round no more signals were received after T + 86 sec.

Magnetometer and temperature gauge worked properly.

Vehicle Performance:

The spin rate was constant at 7.5 rps during the time in which signals were received. The measured temperature increased from 130 deg F at T + 51 sec (approximately 200,000 ft altitude) to 180 deg F at T + 85 sec (approximately 280,000 ft altitude).

TMA Trail Results:

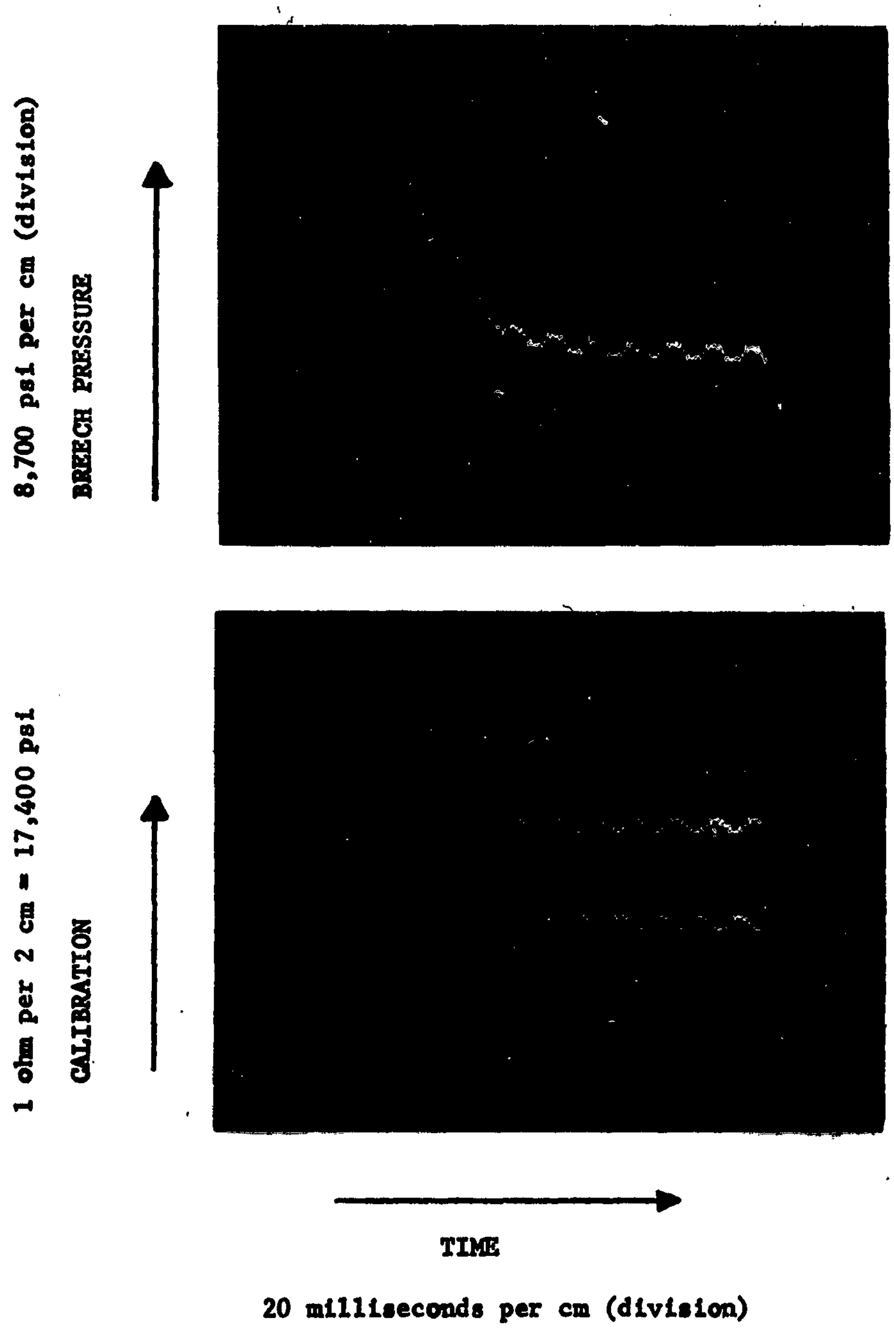
The TMA trail was photographed at Tobago South only, owing to extreme cloud conditions at the other sites. No wind data could therefore be obtained.

Summary:

Vehicle and TMA payload performed satisfactorily. Telemetry did not function properly, and no wind shear data were obtained because of weather conditions.

DIANA

10 JUNE 1965 - 0235 HR AST



Maximum Breech Pressure: Pmax = 43,200 psi

Fig. 16 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND DIANA

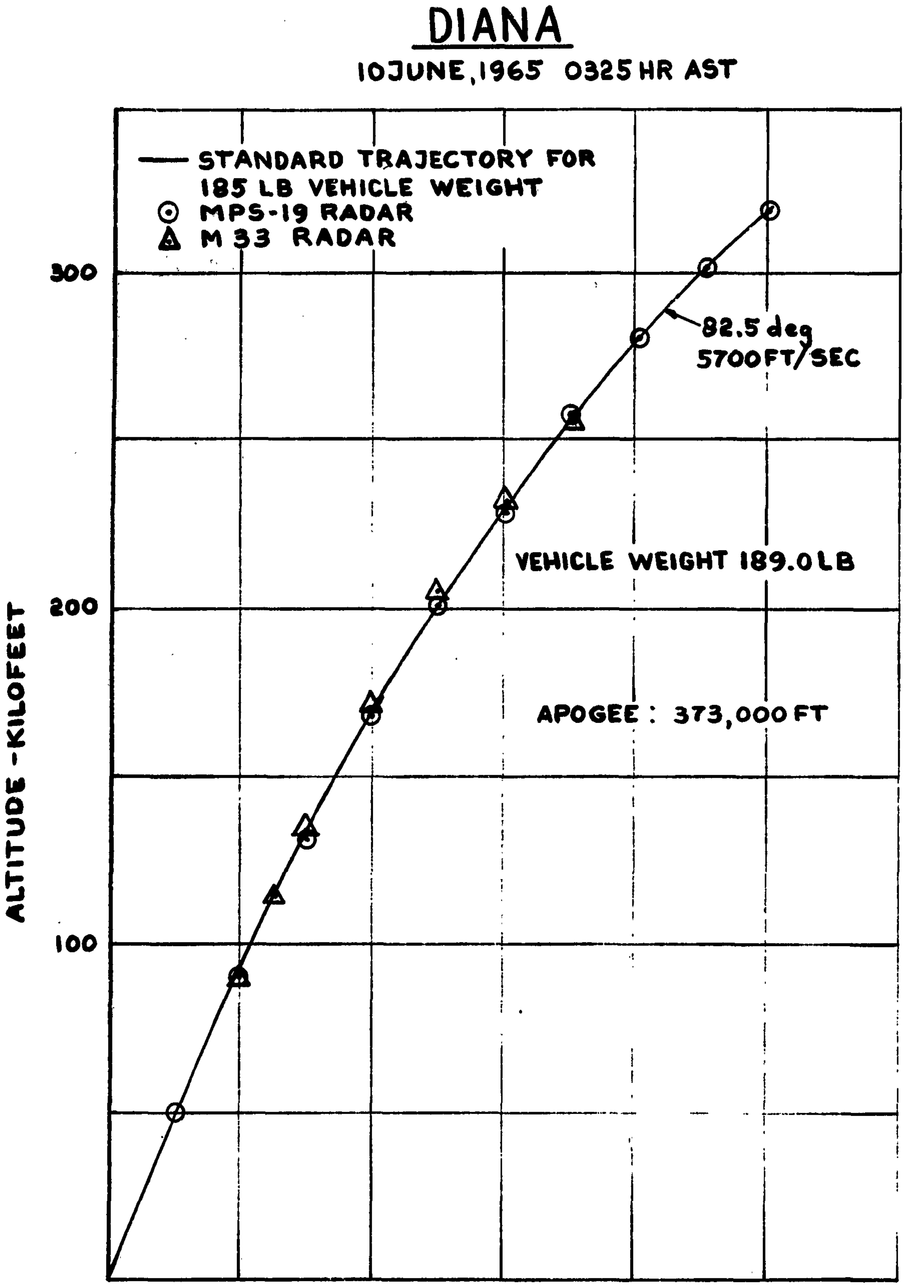


FIG. 16a MARTLET 2C SHOT DIANA
ALTITUDE VS TIME

DIANA

10 JUNE, 1965 0325 HR AST

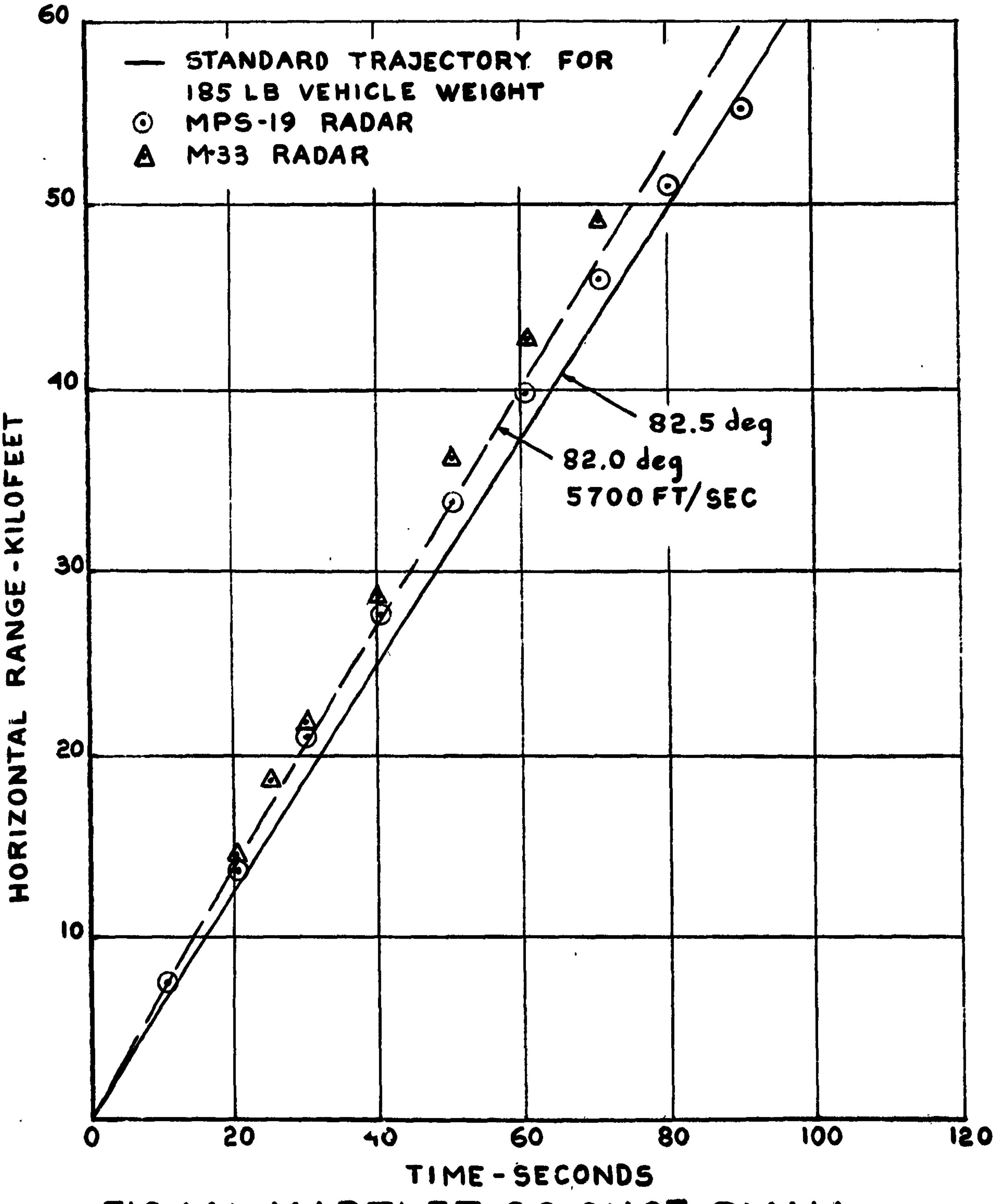


FIG. 16b MARTLET 2C SHOT DIANA
RANGE VS TIME

DIANA

10 JUNE, 1965 0235 HR AST

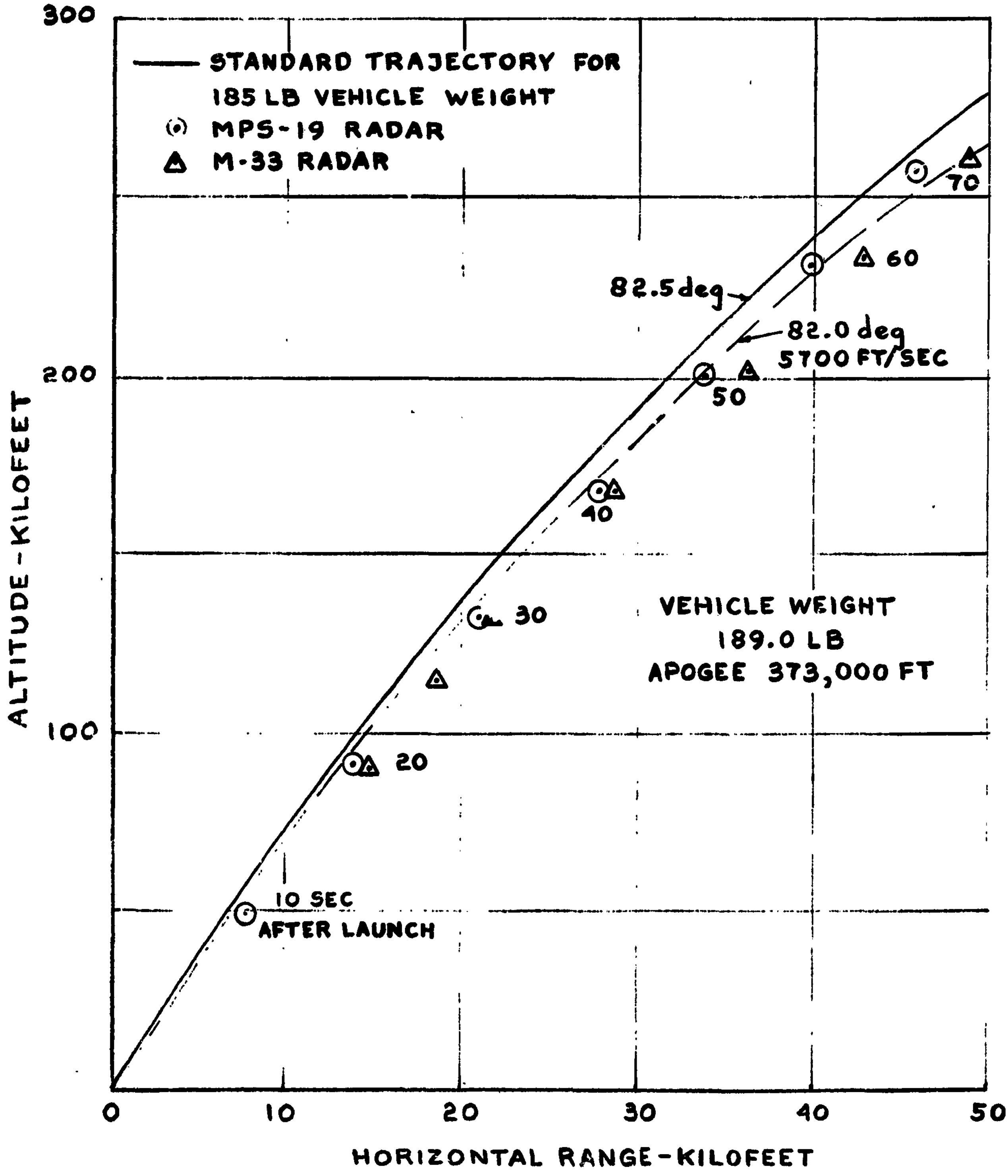


FIG. 16c MARTLET 2C SHOT DIANA
ALTITUDE VS RANGE

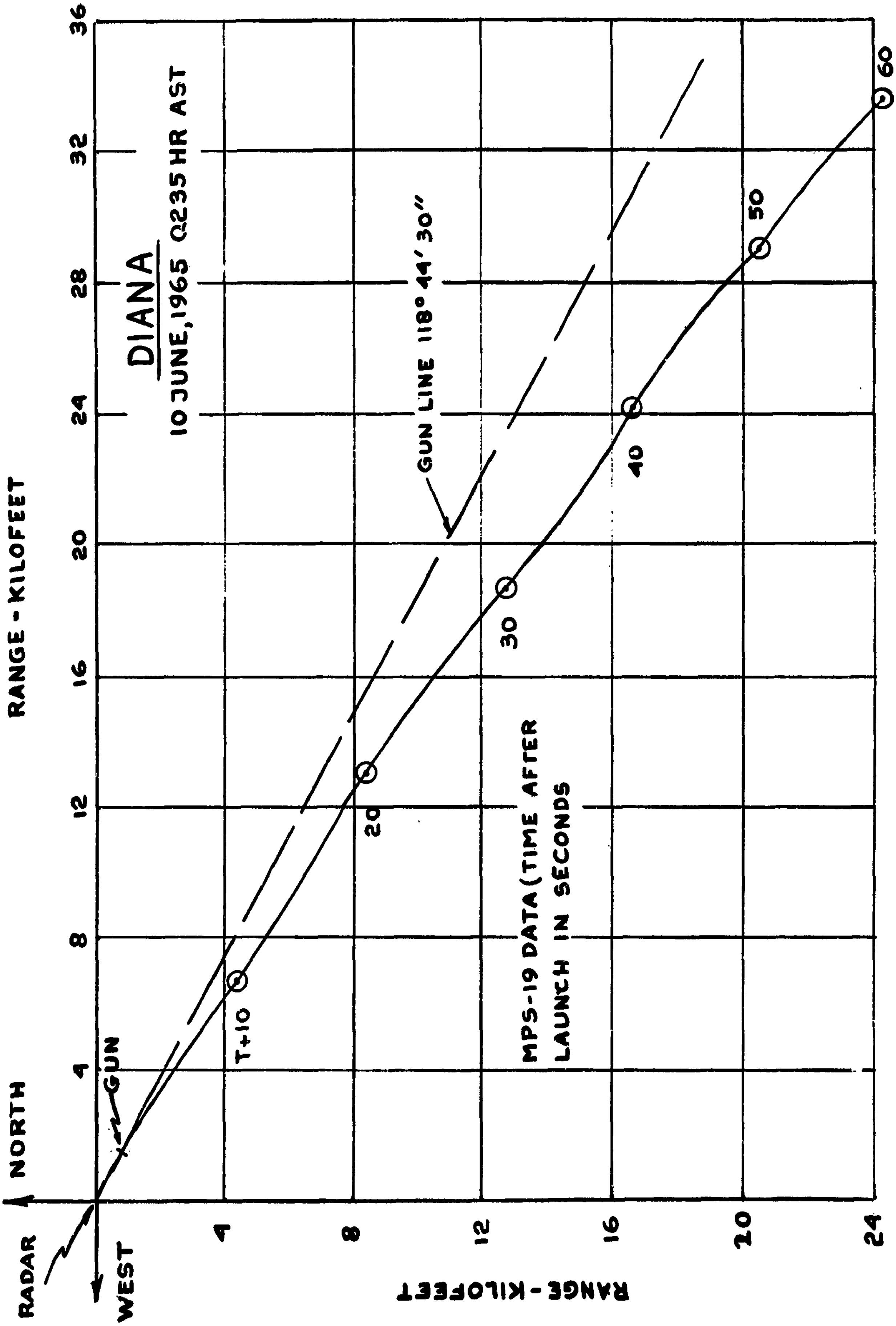


FIG.16d PLAN VIEW OF MARTLET 2C DIANA TRAJECTORY

4.5.10 Round No. 18 - PLINY

Date: 11 June, 1965 - 2107 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb TMA to be ejected at T + 65 sec.

Purpose of Test: Synoptic measurements of wind profiles.

Weights:

Vehicle	187.25 lb
Pusher and Obturator	125.00 lb
Sabot	102.50 lb
Shot Weight	414.75 lb

Centre of Gravity: 22.3 in. from base.

Modification to Pusher Plate:

The consistent tendency for vehicles to fly off gun line (at an azimuth angle of approximately 125 deg) at the higher launch velocities led to the conclusion that the pusher plate was being damaged during launch. A large unrepaired gouge so located as to account for this general azimuth direction change existed in the gun barrel. To overcome this problem, the pusher plate was modified in the following way. A 3 inch aluminum ring was attached to the front end of the plate, screwing 1 inch on to the maraging steel threads and extending forward approximately 2 inches. In addition, a 3/4 inch brass rider ring was placed in the middle of the pusher plate.

While this modification was in progress, the entire pusher plate of the DIANA round was recovered, and the predicted wear pattern was observed.

Launch Data:

Charge Weight	780 lb M8M (8 bags)
Swedish Additive	18 sheets
Igniter	500 grams/bag
Gun Elevation	82.5 degrees
Crusher Gauges	M11 - 4
	Mk6 - 2
Ram Distance	192 in
Ram Load	17 tons
Chamber Volume	40,800 in^3
Recoil	39.8 in
Breech Pressure	M11 44,800 psi
	Mk6 46,500 psi
	Strain 41,800 psi (Fig. 17)
Muzzle Velocity Probe	left 6,850 ft/sec
	right 6,140 ft/sec

Radar Records:

The MPS-19 radar tracked normally. For the M-33 radar the target was too fast. However, an approximate point check was obtained for T + 50 sec.

Trajectory:

The radar data are plotted in Figs. 17a to 17d in comparison with a standard drag trajectory for 6,100 ft/sec muzzle velocity at 82.5 deg launch angle. The agreement is satisfactory. The vehicle also followed the gun line, confirming the above assumption regarding the pusher plate tipping.

An apogee of 436,000 ft = 133 kilometers was achieved; St. Vincent reported the figure of 126 kilometers.

Estimated total range 216,000 ft.

TMA Trail Results:

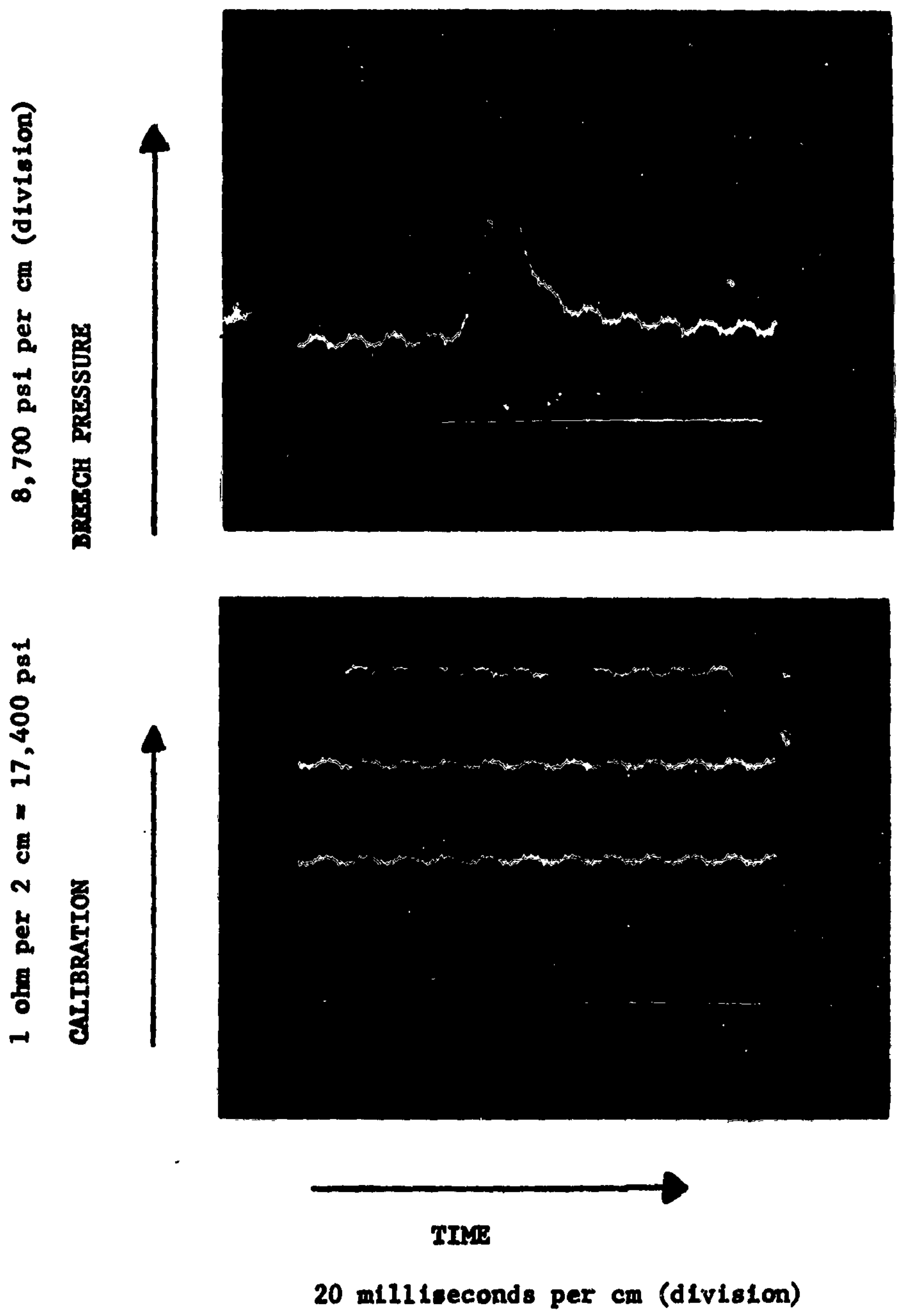
Payload and cameras performed satisfactorily. Wind shear data were obtained from 97 to 108 kilometers.

Summary:

Successful round, with a trajectory as expected, and good results of wind shear data.

PLINY

11 JUNE 1965 - 2107 HR AST



Maximum Breech Pressure: Pmax = 41,800 psi

Fig. 17 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND PLINY

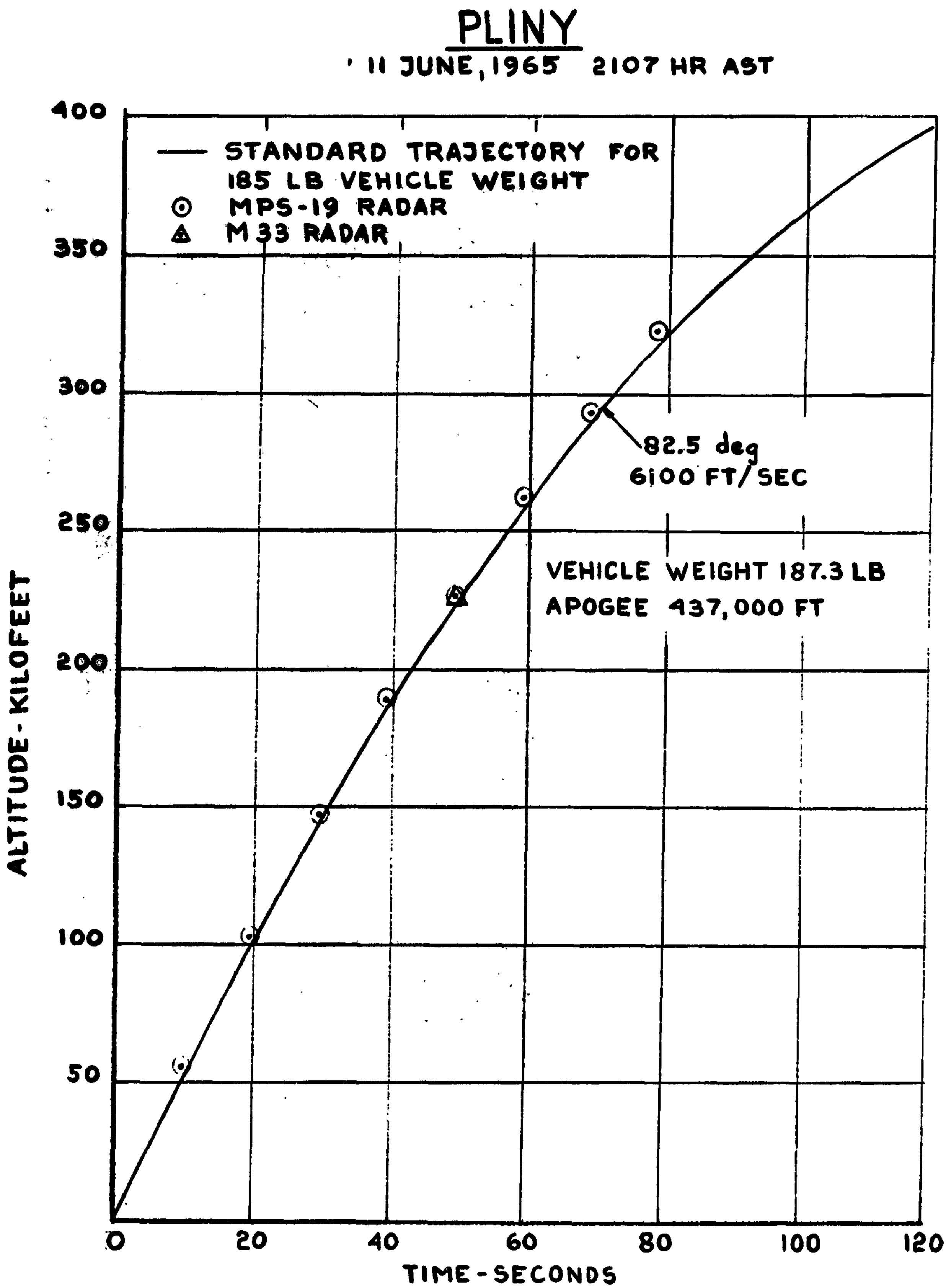


FIG. 17a MARTLET 2C SHOT PLINY

ALTITUDE VS TIME

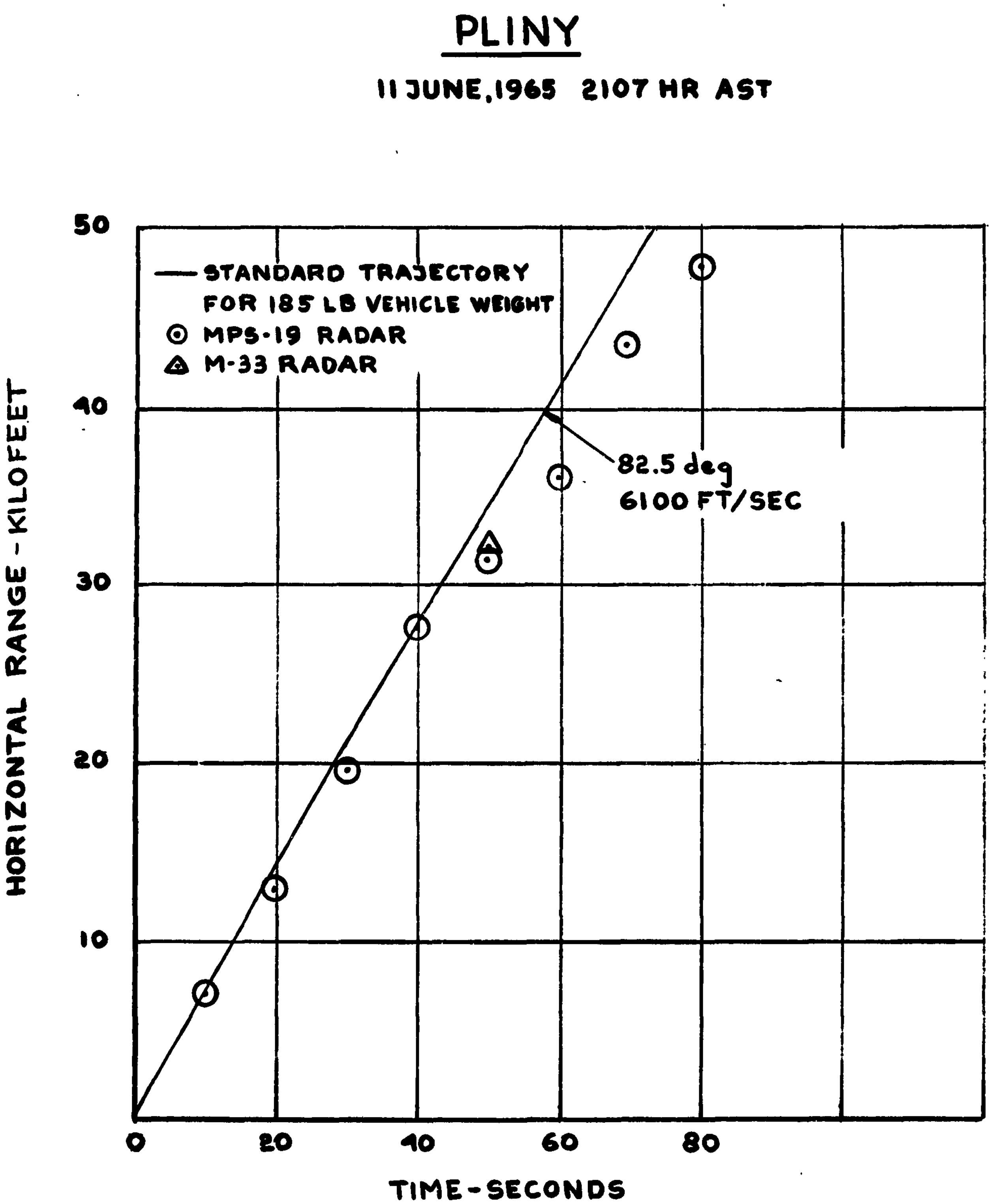


FIG. 17b MARTLET 2C SHOT PLINY

RANGE VS TIME

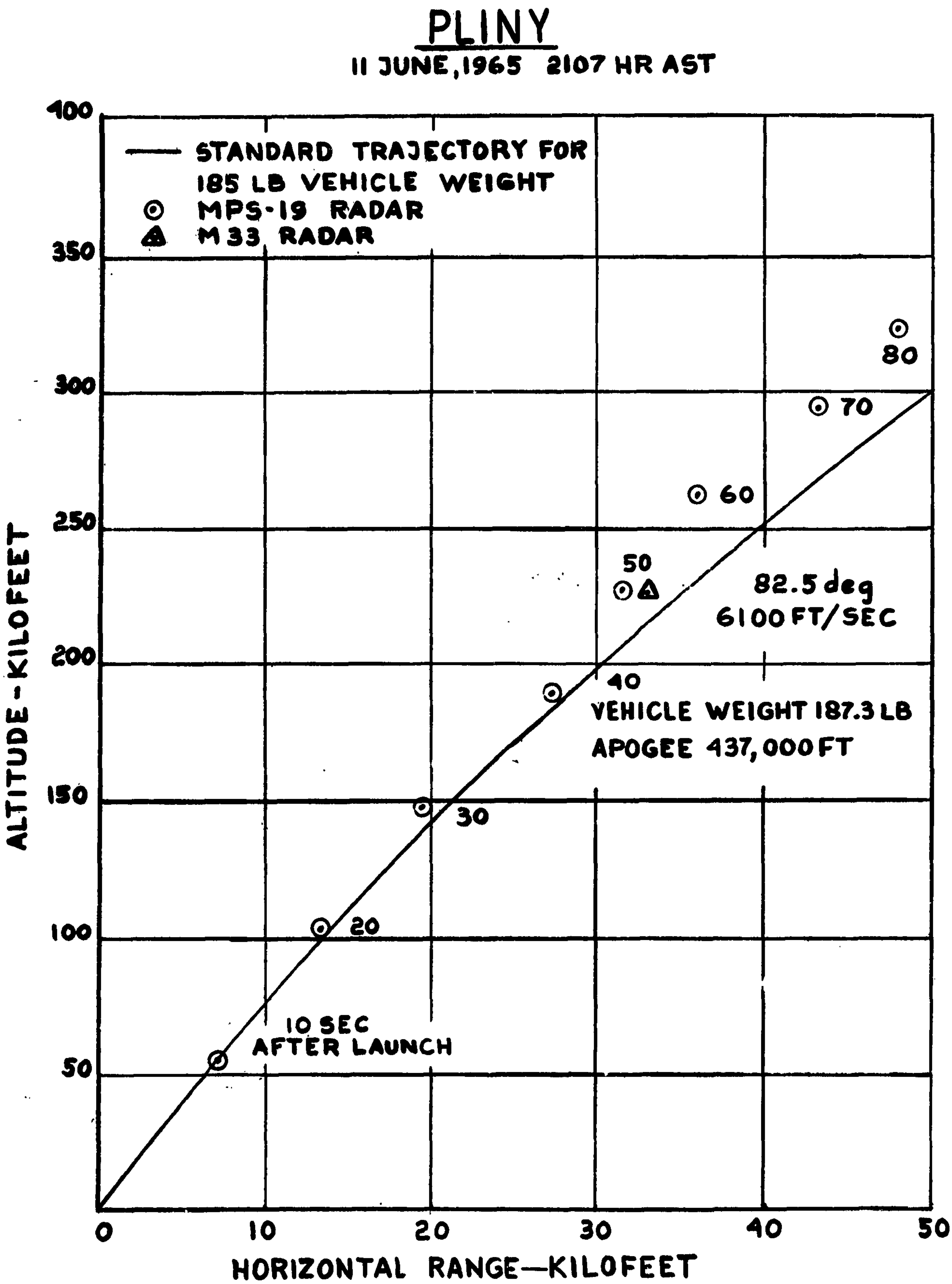


FIG.17c MARTLET 2C SHOT PLINY
ALTITUDE VS RANGE

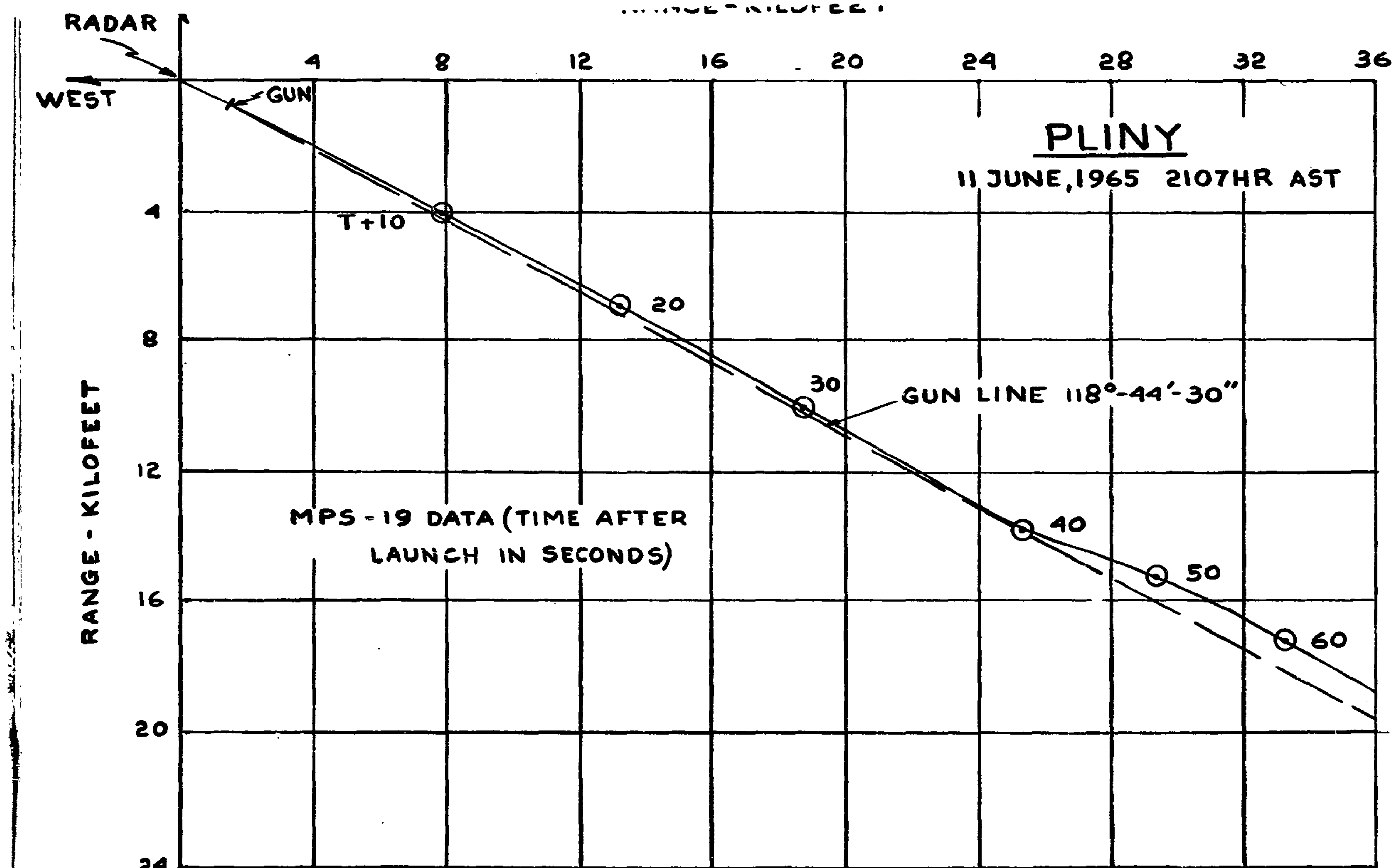


FIG.17d PLAN VIEW OF MARTLET 2C PLINY TRAJECTORY

4.5.11 Round 19 - QUINTUS

Date: 12 June, 1965 - 0300 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb TMA to be ejected at T + 65 sec.

Purpose of Test: Synoptic measurements of wind profiles.

Weights:

Vehicle	187.50 lb
Pusher and Obturator	125.50 lb
Sabot	102.50 lb
Shot Weight	415.50 lb

Centre of Gravity: 22.25 in. from base.

Launch Data:

Charge Weight	790 lb M8M (8 bags)
Swedish Additive	18 sheets
Igniter	500 grams/bag
Gun Elevation	85 degrees
Crusher Gauges	M11 - 4
	Mk6 - 3
Ram Distance	192 in
Ram Load	18 tons
Chamber Volume	40,800 in^3
Recoil	40.5 in
Breech Pressure	M11 49,300 psi
	Mk6 45,700 psi
	Strain 45,200 psi (Fig. 18)
Muzzle Velocity Probe	Left 6,060 ft/sec
	Right 6,050 ft/sec

Note: A modified pusher plate was used as described for the preceding round.

Radar Records:

Both the MPS-19 and M-33 radars tracked the vehicle almost to apogee. For the M-33 radar the velocity was so high that measurements were not attempted before T + 50 sec.

Again an off-azimuth course up to approximately 5 deg was obtained. The skirt modification piece attached to the front of the original pusher (as described for PLINY) was recovered and indicated in-barrel damage.

Trajectory:

The radar data are in good agreement with the standard drag trajectory for 6,150 ft/sec at 85 deg launch angle. In spite of the off-azimuth flight the drag was apparently about standard or even below standard considering the muzzle velocity obtained from the probes.

The near-standard drag was confirmed by the achievement of an apogee of 444,000 ft = 135 kilometers, which established a new record.

Estimated total range 148,000 ft.

TMA Trail Results:

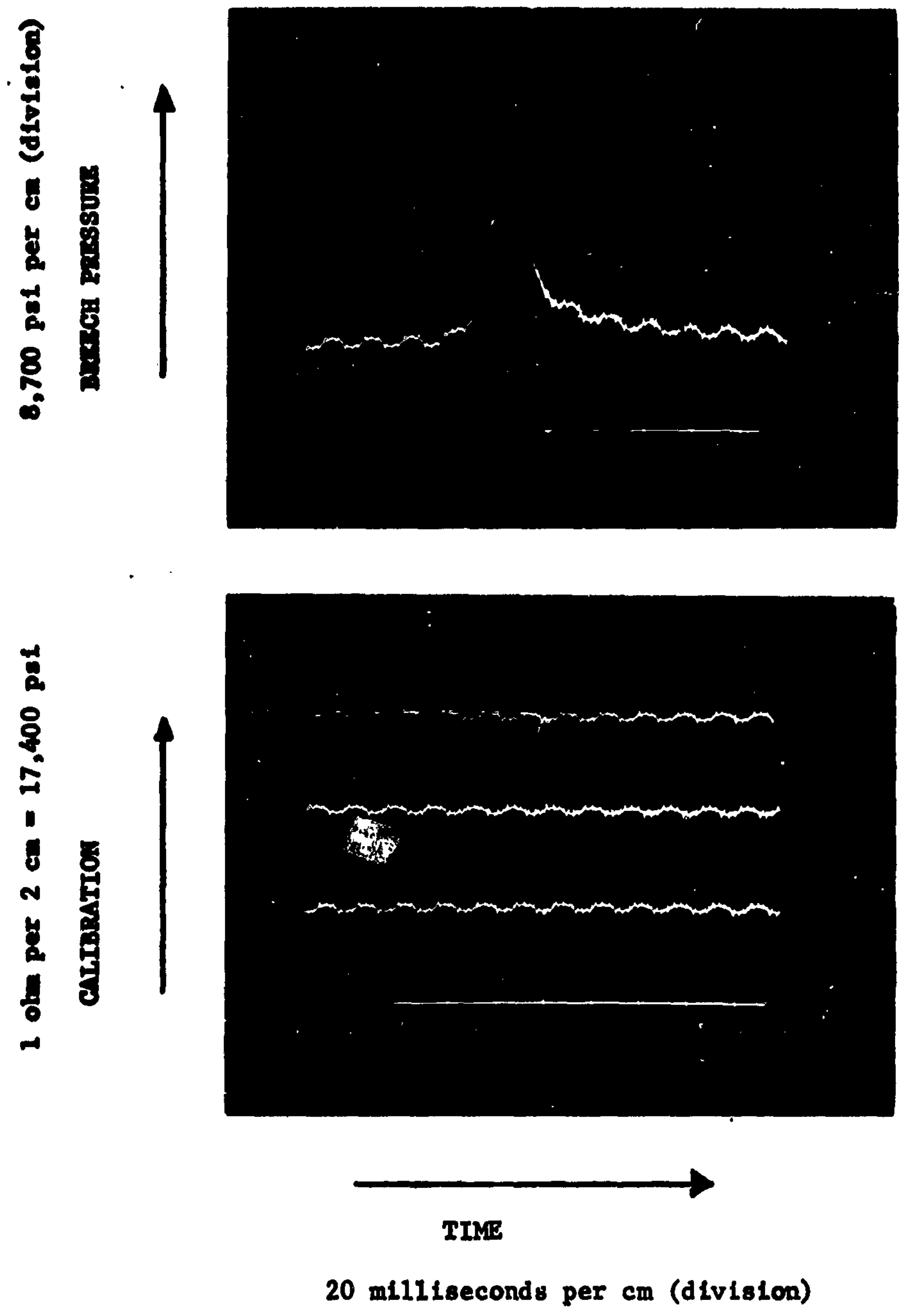
Owing to extremely bad cloud conditions, trail photographs were obtained mainly from the Barbados sites, and only sporadically from the other stations. No wind data could be obtained.

Summary:

Successful flight; with record apogee.

QUINTUS

12 JUNE 1965 - 0300 HR AST



Maximum Breech Pressure: Pmax = 45,200 psi

Fig. 18 STRAIN GAUGE RECORD OF BREECH PRESSURE ROUND QUINTUS

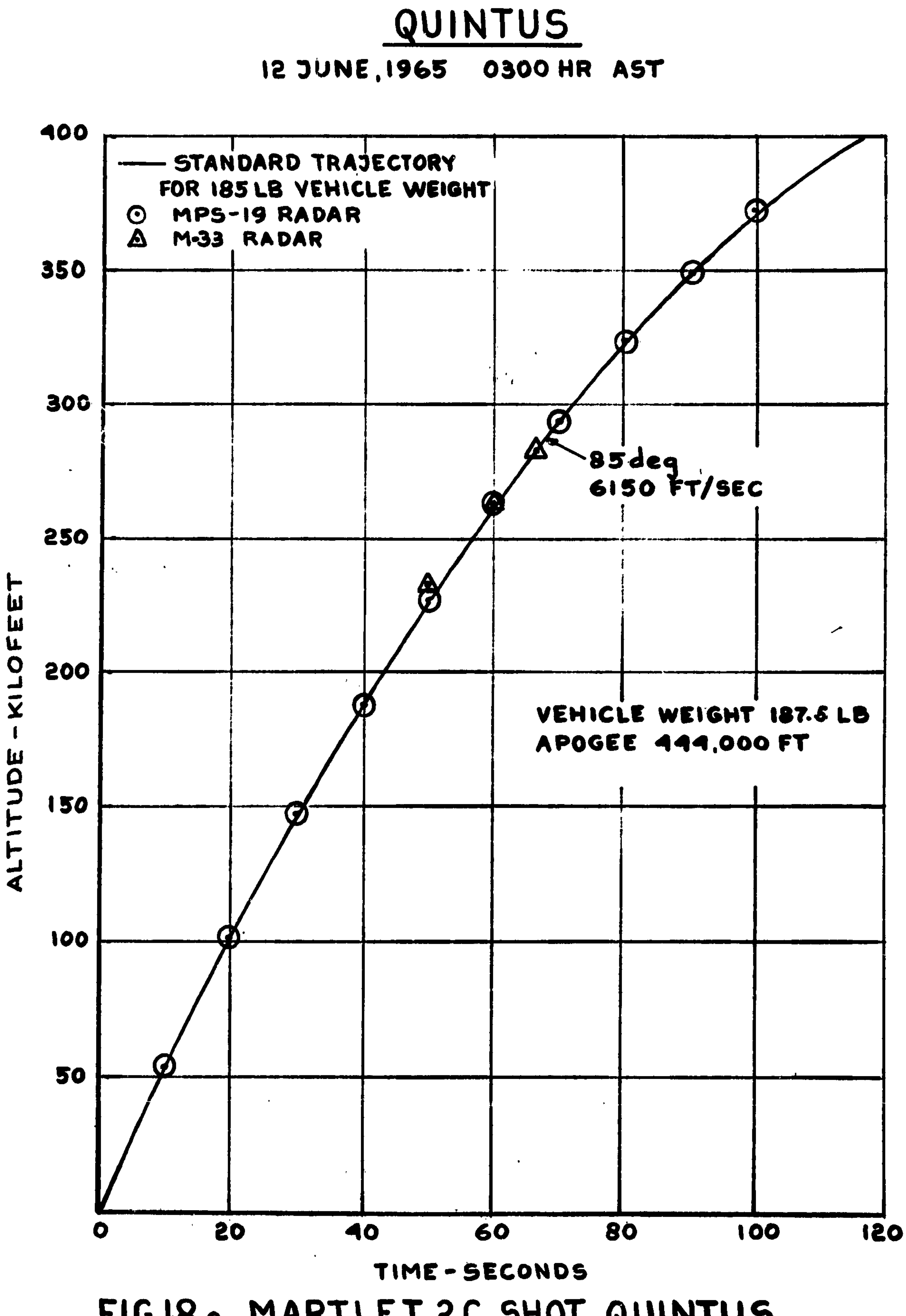


FIG 18a MARTLET 2C SHOT QUINTUS
ALTITUDE VS TIME

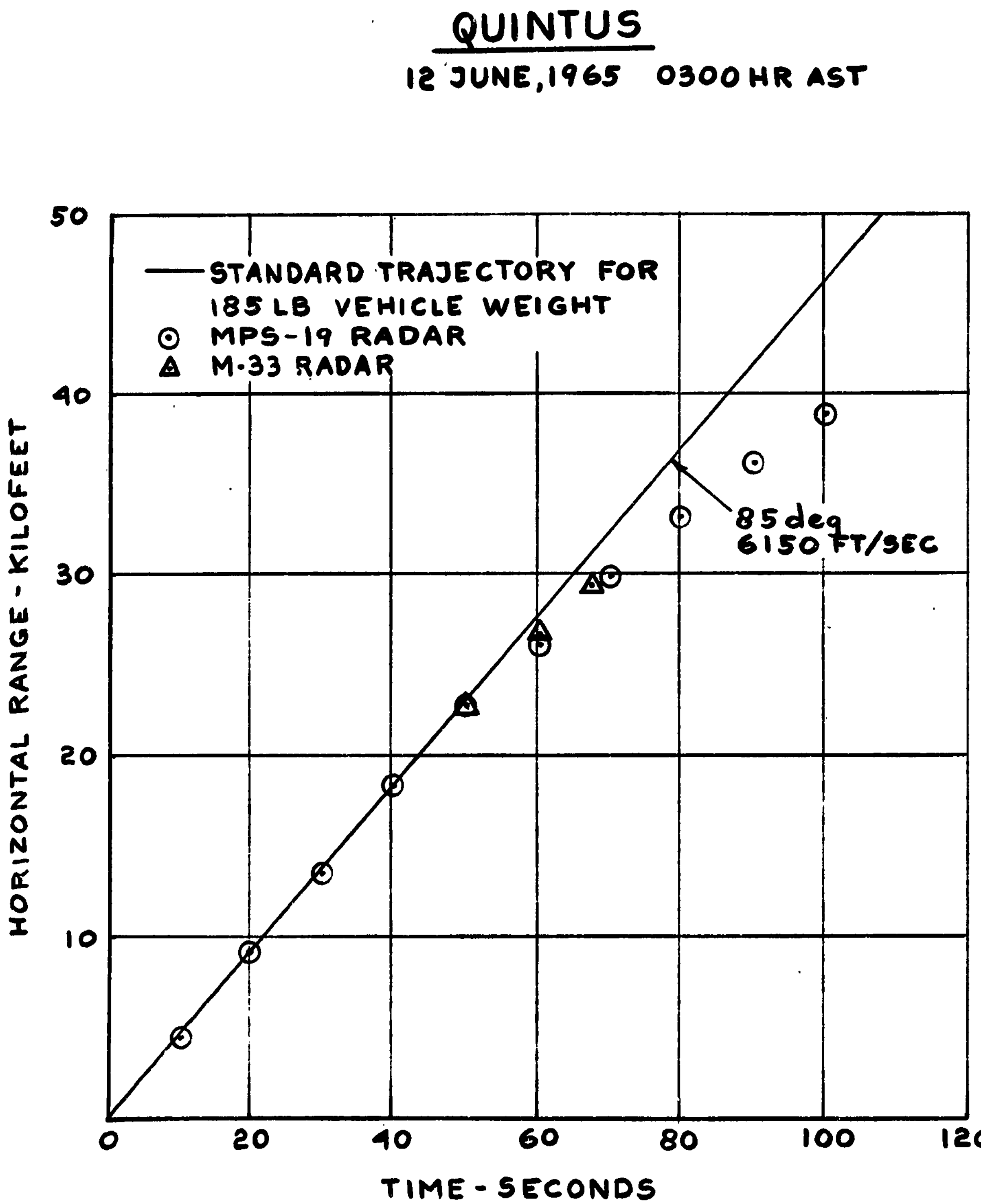


FIG. 18b MARTLET 2C SHOT QUINTUS
RANGE VS TIME

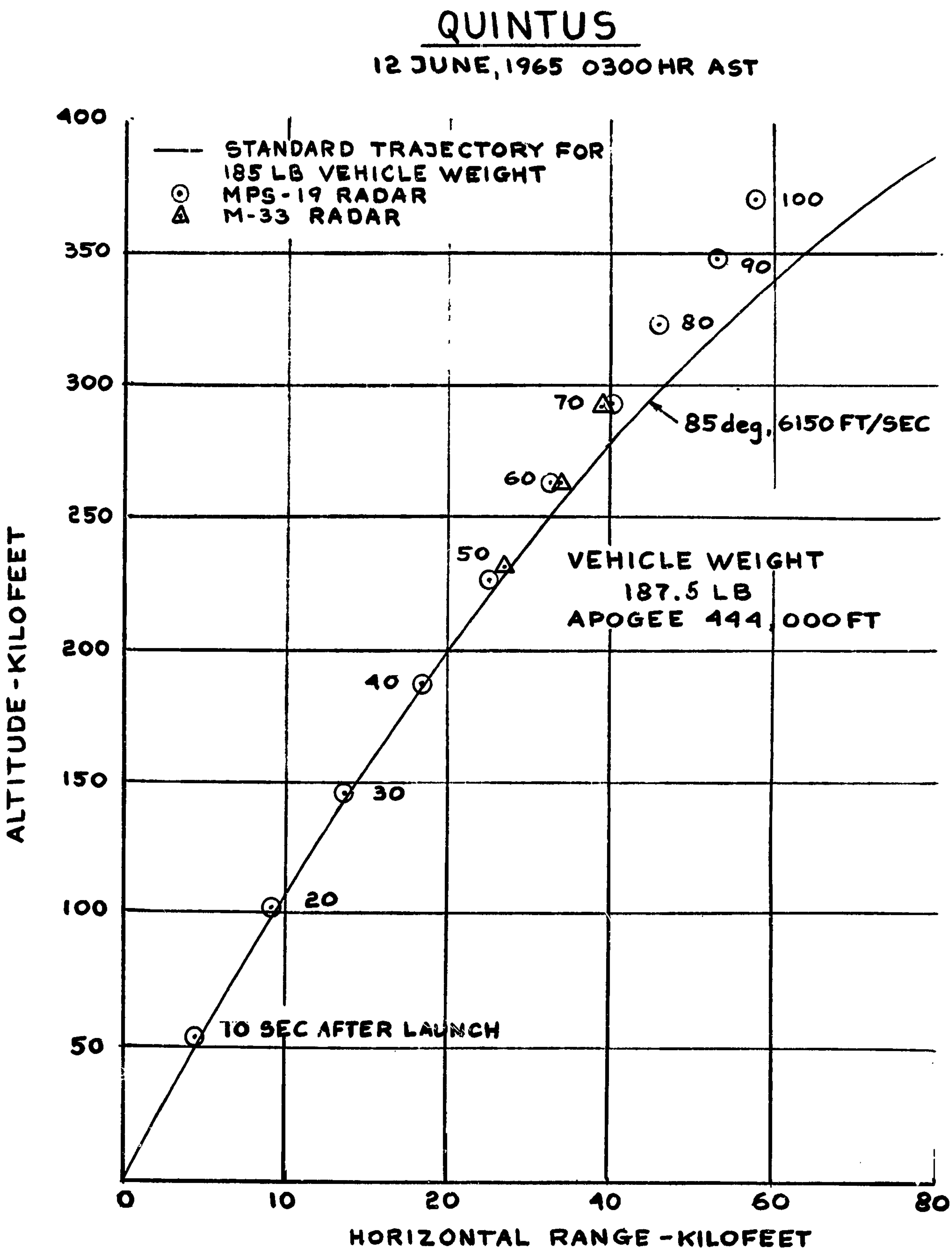


FIG. 18c MARTLET 2C SHOT QUINTUS

ALTITUDE VS RANGE

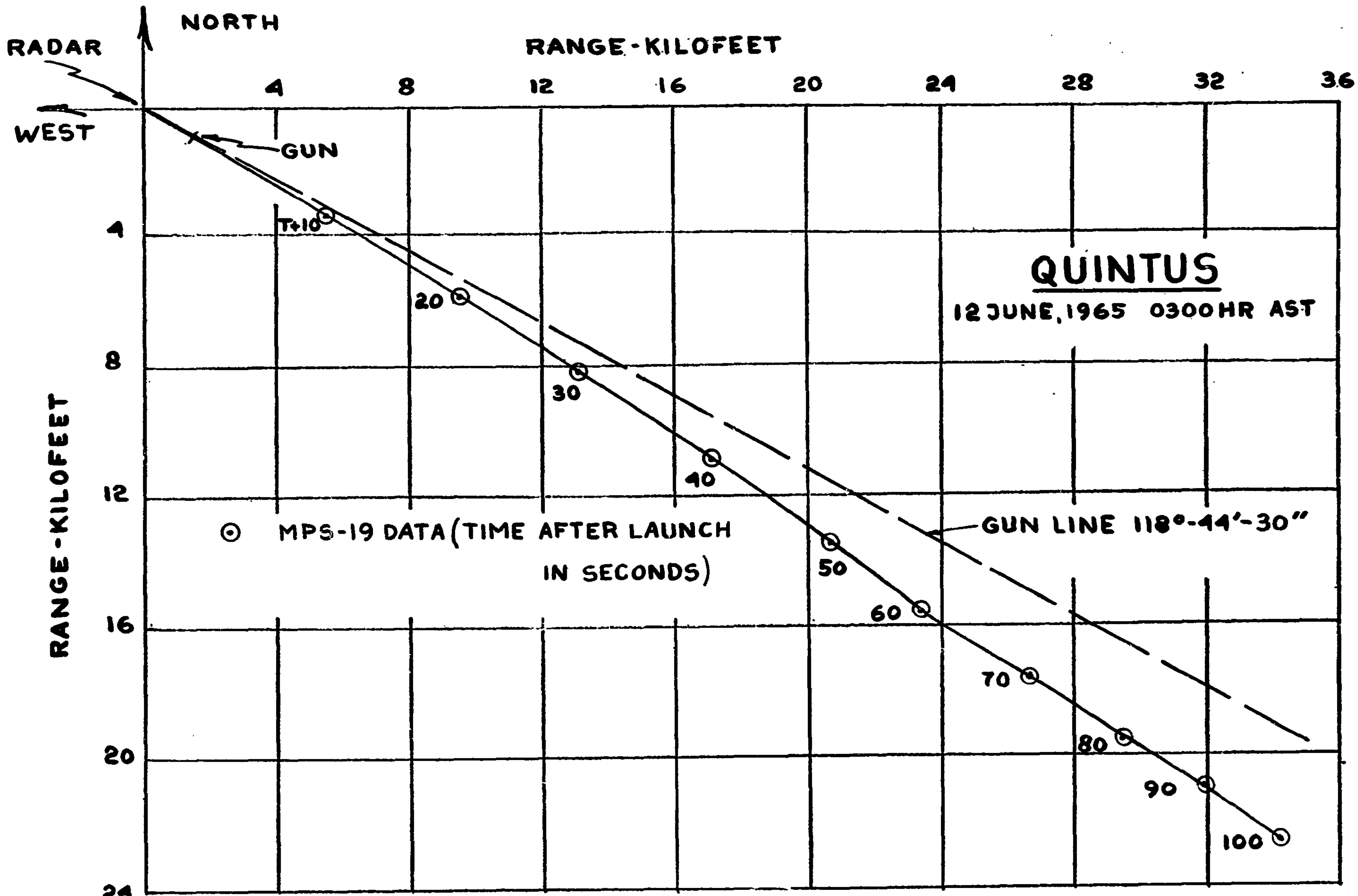


FIG.18d PLAN VIEW OF MARTLET 2C QUINTUS TRAJECTORY

4.5.12 Round No. 20 - HADRIAN

Date: 12 June, 1965 - 0431 hr A.S.T.

Vehicle Description: Martlet 2C carrying 5.5 lb of TMA to be ejected at T + 65 sec.

Purpose of Test: Synoptic measurements of wind profiles.

Weights:

Vehicle	188.5 lb
Pusher and Obturator	127.0 lb
Sabot	102.5 lb
Shot Weight	418.0 lb

Centre of Gravity: 22 in. from base.

Launch Data:

Charge Weight	780 lb M8M (8 bags)
Swedish Additive	18 sheets
Igniter	500 grams/bag
Gun Elevation	85 degrees
Crusher Gauges	M11 - 4
	Mk6 - 2
Ram Distance	192 in
Ram Load	16 tons
Chamber Volume	40,800 in^3
Recoil	40.25 in
Breech Pressure	M11 44,100 psi
	Mk6 42,100 psi
	Strain 40,000 psi (Fig. 19)
Muzzle Velocity Probe	left 6,050 ft/sec
	right 5,600 ft/sec

Note: A modified pusher plate was used as described for round 18 (p. 110).

Radar Records:

Both radars tracked the vehicle, the MPS-19 up to 414,000 ft which is a new high for this radar.

Trajectory:

The radar data agreed with a standard drag trajectory for 6,150 ft/sec and 86 deg launch angle, whereas the records give 85 deg (Fig. 19a to 19c).

The vehicle flew on the gun line (Fig. 19d) which indicates that the modified plate served its purpose.

An apogee of 438,000 ft was achieved, in good agreement with the standard drag trajectory.

Estimated total range 148,000 ft.

TMA Trail Results:

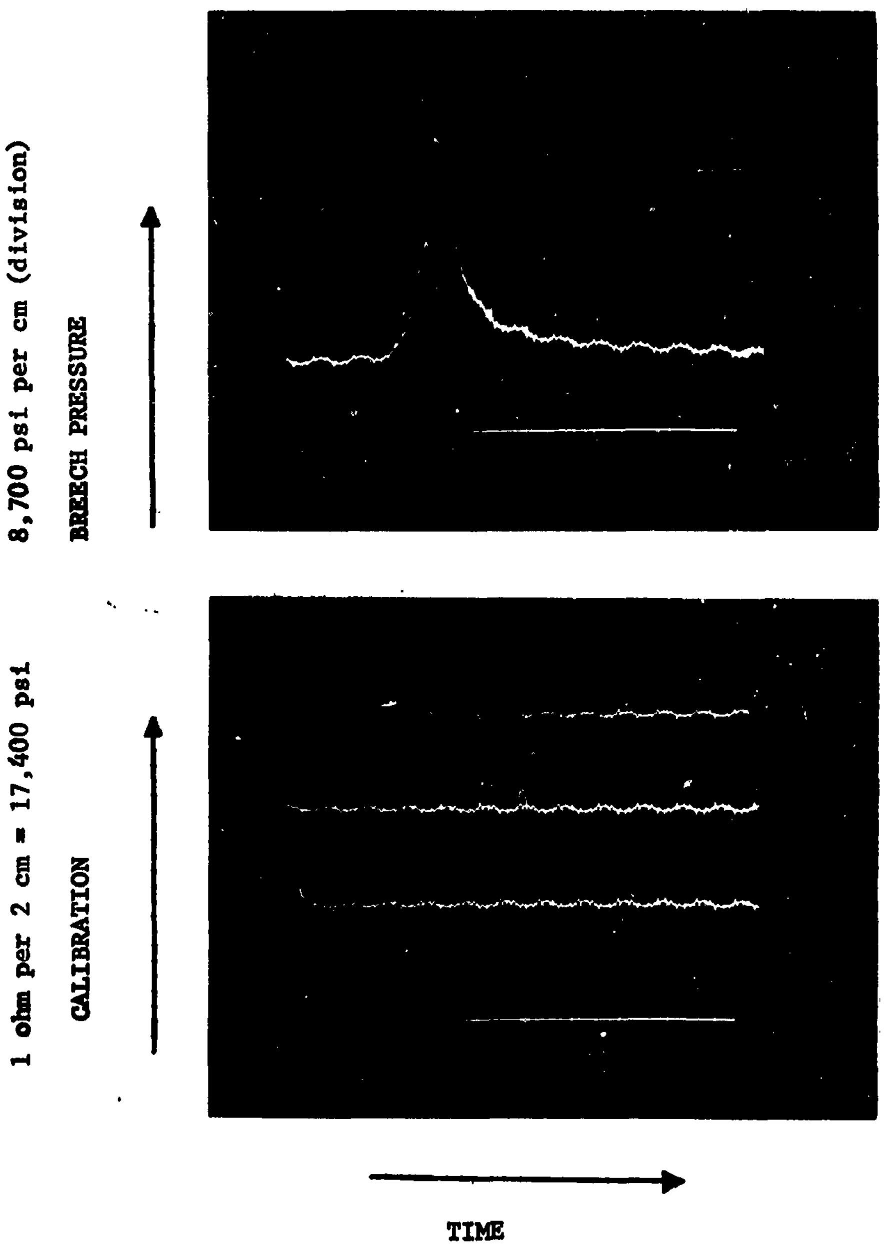
The flight occurred with the solar horizon at about 70 kilometers. K-24 camera coverage was obtained by all stations. No wind data, however, could be obtained from the photographs.

Summary:

Successful round, repeating the result of QUINTUS.

HADRIAN

12 JUNE 1965 - 0431 HR AST



20 milliseconds per cm (division)

Maximum Breech Pressure: Pmax = 40,000 psi

Fig. 19 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND HADRIAN

HADRIAN

12 JUNE, 1965 0431 HR AST

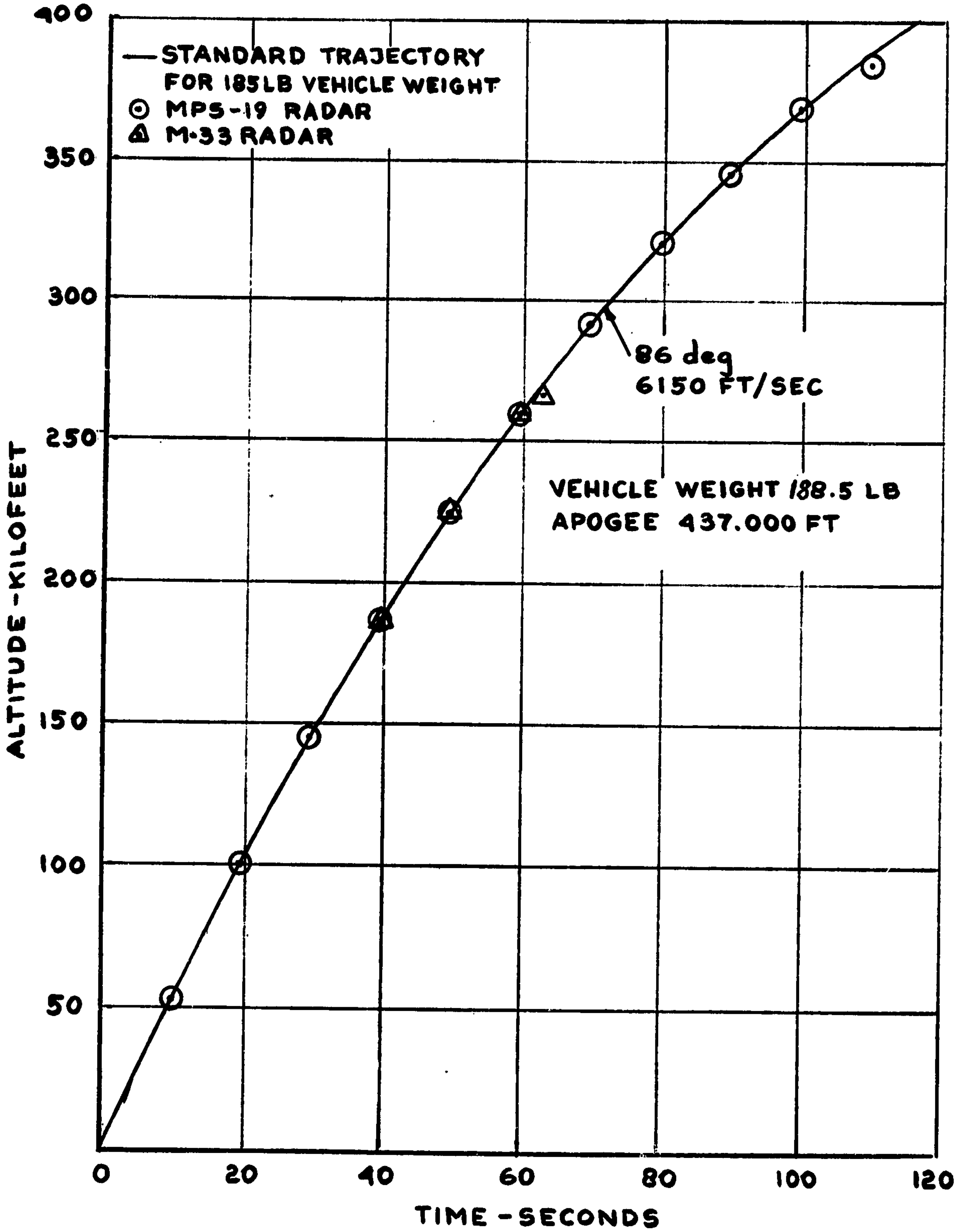


FIG. 19a MARTLET 2C SHOT HADRIAN

ALTITUDE VS TIME

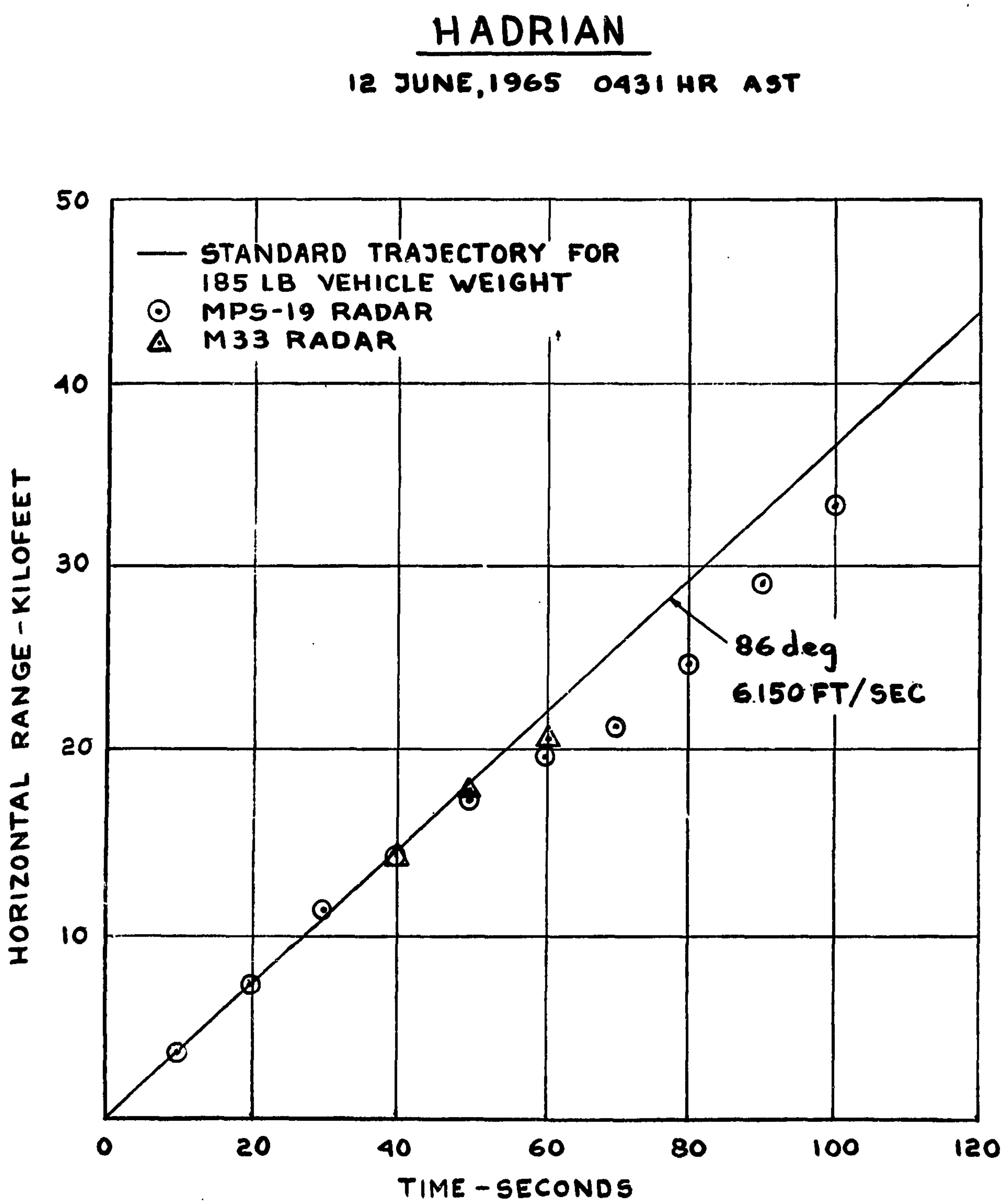


FIG.19b MARTLET 2C SHOT HADRIAN
RANGE VS TIME

HADRIAN

12 JUNE, 1966 0431 HR AST

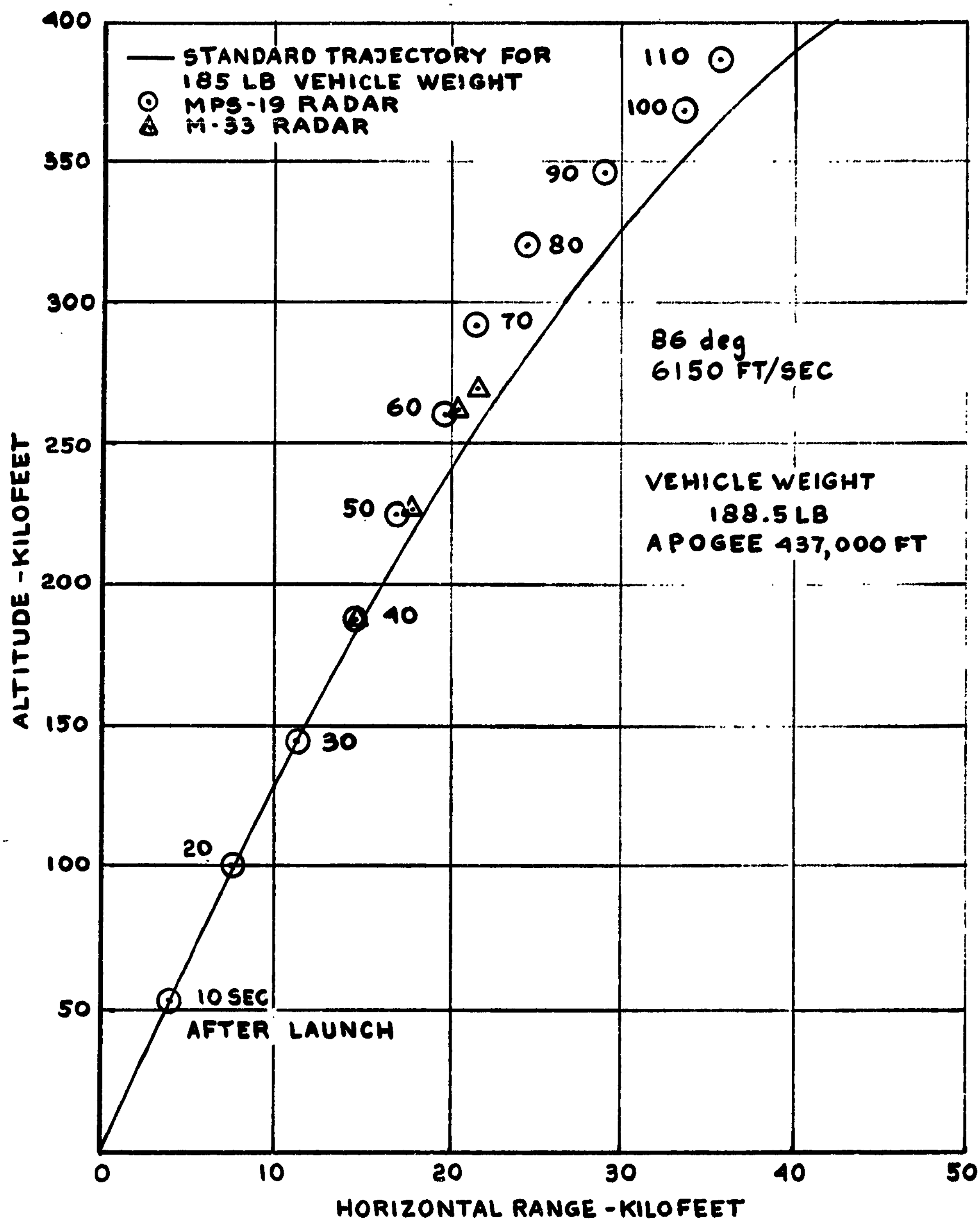


FIG.19c MARTLET 2C SHOT HADRIAN

ALTITUDE VS RANGE

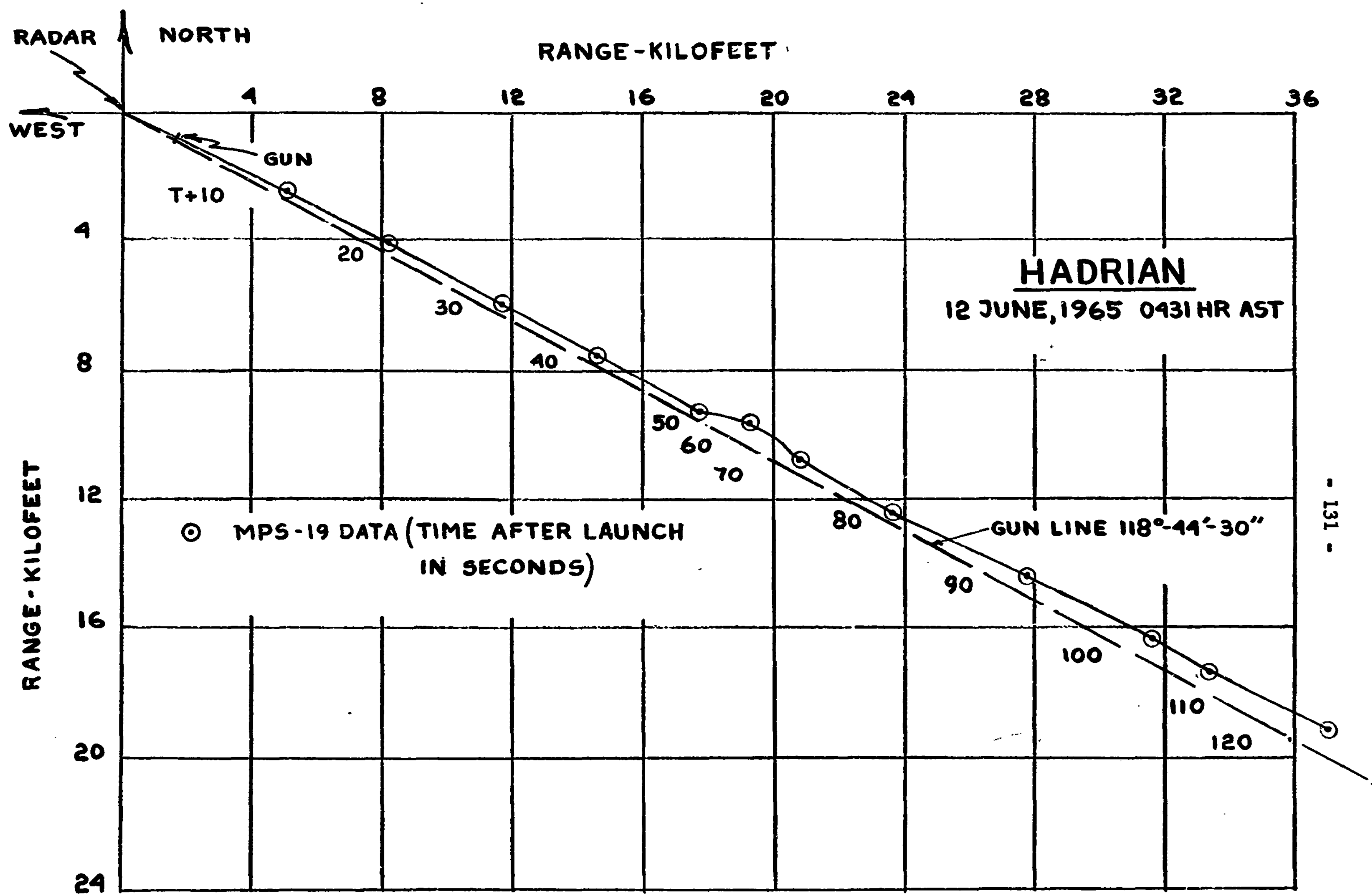


FIG. 19d PLAN VIEW OF MARTLET 2C HADRIAN TRAJECTORY

5.0 THE MARTLET 2C MOD. 1 SERIES

5.1 Vehicle

These vehicles have the same aerodynamic (i.e. external) configuration as the Martlet 2C. The internal profile, however, has been modified to accept instrumentation for measurements of electron density in the upper atmosphere by the Ballistic Measurements Laboratory (BML) of BRL (Fig. 20).

5.2 Payload

One of the three vehicles of this series contained a DC Langmuir Probe, a magnetometer, and a number of thermistor temperature gauges. The temperature data points were sampled by means of a 7 channel commutator, and two voltage controlled subcarriers modulated the transmitter. The measured data were telemetered on a 1750 MHz carrier, by utilizing a rear cavity antenna.

The other two vehicles carried AC Langmuir probes and a magnetometer; no temperature measurements were made. The payloads are described in detail in Section 9.3.

5.3 Predicted Performance

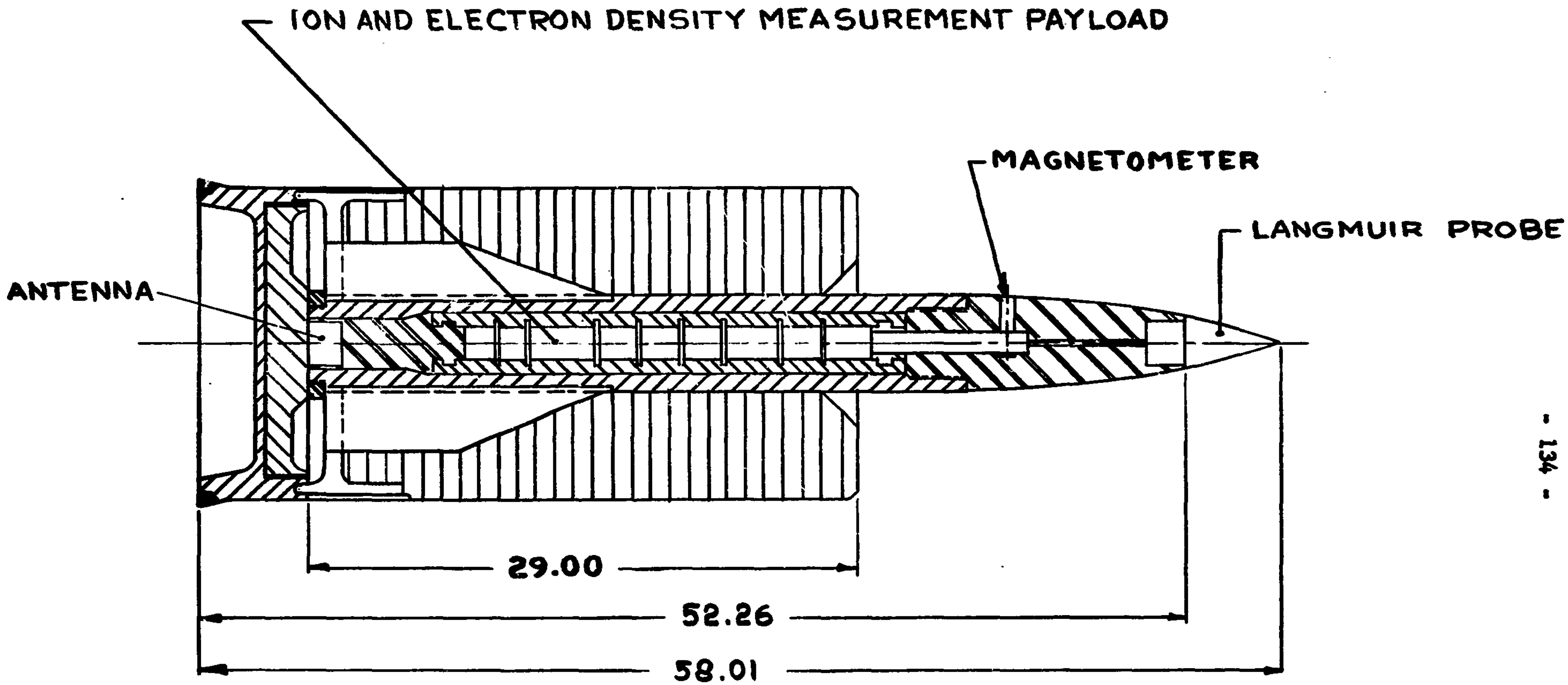
Since the aerodynamics and vehicle weight were the same as for Martlet 2C, the trajectories shown in Fig. 7 apply also to the Mod. 1 version of this vehicle.

5.4 Firing Program

The three rounds were BRUTUS, IRE, and JANUS, the latter two with the AC probe.

IRE had an azimuth deviation due to a pusher plate problem, and could not be tracked by radar. Telemetry, however, was received, indicating a slightly shorter flight time than expected. The other two flights were on trajectory with good telemetry on all channels.

Summarized flight results of the three rounds are presented in Table IV, and detailed flight performance data in paragraph 5.5. The results of the measurements are discussed in Section 9.2.



MARTLET 2C MOD1

LANGMUIR PROBE

FIG. 20

TABLE IV

MAY/JUNE 1965 TEST PROGRAM - MARTLET 2C MOD. 1 SERIES

Flight	Vehicle Description	Weight (lb)	Launch Data	Breech Pressure (psi)	Muzzle Velocity (ft/sec)	Apogee ft(km)	Comments
4 (111) IRE 3/6/65 1654 hr AST QE 86 deg	Martlet 2C Mod.1 carrying 7 channel BML/GCA 1750 MHz telemetry recording AC Langmuir probe readings and vehicle temperature.	Wv: 193.0 Ws: 419.5 C: 725 (M8M)	RD: 185 in RL: 90 tons ChV: 39,110 in^3 Rec: 39.75 in	St: 35,600 M11:40,300	P: [illegible] 5950 - R: - EF: 5880 WF: 5910	-	Successful flight with regards to telemetry. No trajectory data due to damaged fins.
11(118) BRUTUS 5/6/65 1620 hr AST QE 82.5 deg	Martlet 2C Mod.1 carrying a DC Langmuir probe, magnetometer, and temperature gauges. A 7 channel 1750 MHz telemetry (BML) was used.	Wv: 192.0 Ws: 419.0 C: 750 (M8M)	RD: 189 in RL: 30 tons Chv: 40,160 in^3 Rec: 37.0 in	St: 37,300 M11:41,200	P: 5950 5700 5830 R: 5900 EF: 6000 WF: 6020 S: 5620	Radar 390,700 (119)	Successful flight. Good track by radar and telemetry.
12(119) JANUS 5/6/65 1843 hr AST QE 82.5 deg	Martlet 2C Mod.1 carrying an AC Langmuir probe and magnetometer. A 1750 MHz telemetry was used.(BML).	Wv: 192.5 Ws: 419.0 C: 750 (M8M)	RD: 189 in RL: 25 tons Chv: 40,160 in^3 Rec: 37.5 in	St: 37,200 M11:41,200	P: 5890 5980 5940 R: 5850	Radar 386,000 (117)	Successful flight with good radar tracking and telemetry signals. No magnetometer and Langmuir probe data obtained.

Wv: Vehicle Weight
Ws: Shot Weight
C: Charge Weight

RD: Ram Distance
RL: Ram Load
ChV: Chamber Volume
Rec: Recoil

St: Strain Gauge
M11: Crusher Gauge Type

P: Probe 1st Fig. Left
2nd Fig. Right
3rd Fig. Average
R: Radar
WF: West Fastax
EF: East Fastax
S: Double Smear

5.5 Detailed Flight Performance

5.5.1 Round No. 4 - IRE

Date: 3 June, 1965 - 1654 hr A.S.T.

Vehicle Description: Martlet 2C (Mod. 1) carrying 7 channel BML/GCA 1750 megacycle telemetry recording AC Langmuir probe readings and vehicle temperature.

Purpose of Test: Electron density measurements.

Weights:	Vehicle	193.0 lb
	Pusher and Obturator	122.5 lb
	Sabot	104.0 lb
	Shot Weight	419.5 lb

Centre of Gravity: 21.5 in. from base.

Launch Data:

Charge Weight	725 lb M8M (8 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	86 degrees
Crusher Gauges	M11 - 4
Ram Distance	185 in
Ram Load	90 tons
Chamber Volume	39,310 in^3
Recoil	39.81 in
Breech Pressure	M11 40,300 psi
	Strain 35,600 psi (Fig. 21)
Muzzle Velocity Probe	right 5,950 ft/sec

Camera Records:

Vehicle launch recorded satisfactorily on all smear cameras. Poor records were obtained in the Fastax and double smear cameras owing to lighting conditions, but the photographs could be evaluated for muzzle velocity values as follows:

West Fastax (6 in. lens, 160 ft ahead of muzzle) - 5,910 ft/sec

East Fastax (10 in. lens, 140 ft ahead of muzzle) - 5,880 ft/sec.

The smear films showed damage on the fins due to the latch arms attached to the pusher plate.

Radar Records:

Neither the M-33 radar nor the MPS-19 radar acquired the vehicle owing to a large azimuth dispersion caused by damaged fins.

Telemetry:

Telemetry recorded on all channels; signals and data were received from 0 to 75, 92 to 99, 109 to 113, and 225 to 233 seconds.

GMD-tracking was accomplished during the first period (0 to 75 seconds), showing that the course of projectile was 230 deg true. A flight apogee in excess of 300,000 ft was also indicated.

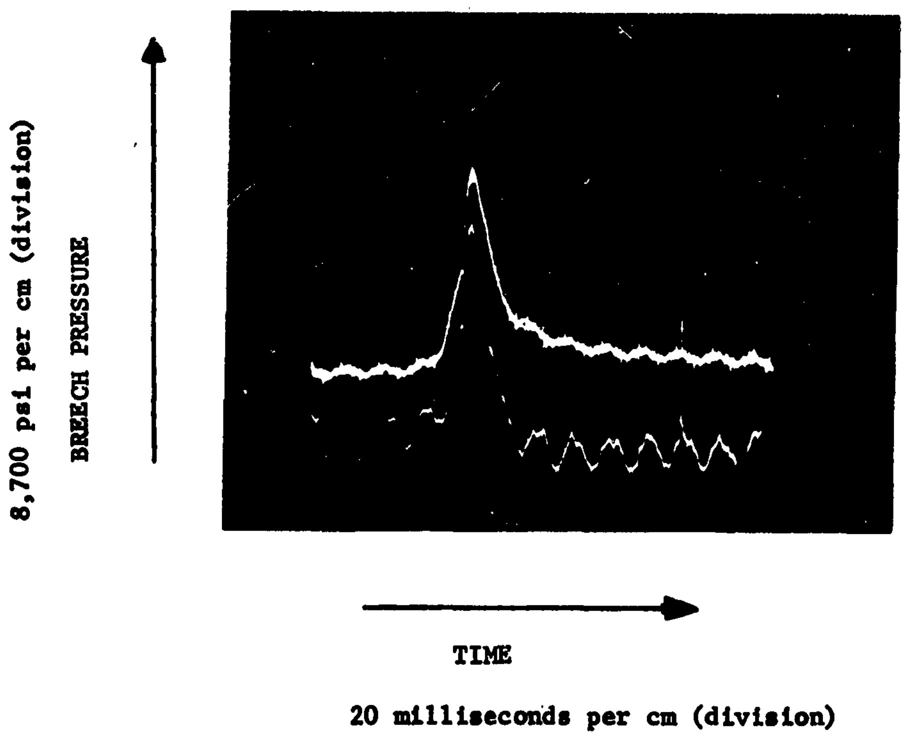
Langmuir probe data were received, but no magnetometer data.

Summary:

This was a moderately successful flight with respect to telemetry. Owing to the damaged fins, however, no trajectory data became available.

IRE

3 JUNE 1965 - 1654 HR AST



Maximum Breech Pressure: Pmax = 35,600 psi

Fig. 21 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND IRE

5.5.2 Round No. 11 - BRUTUS

Date: 5 June, 1965 - 1620 hr A.S.T.

Vehicle Description: Martlet 2C (Mod. 1) carrying a DC Langmuir probe, magnetometer, and temperature gauges. A 7 channel 1750 MHz telemetry was used (BML).

Purpose of Test: Electron density and temperature measurements.

Weights:	Vehicle	192 lb
	Pusher and Obturator	122 lb
	Sabot	105 lb
	Shot Weight	419 lb

Centre of Gravity: 21.4 in. from base.

Launch Data:

Charge Weight	750 lb M8M (8 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	82.5 degrees
Crusher Gauges	M11 - 4
Ram Distance	189 in
Ram Load	30 tons
Chamber Volume	40,160 in^3
Recoil	37 in
Breech Pressure	M11 41,200 psi
	Strain 37,300 psi (Fig. 22)
Muzzle Velocity Probe	Left 5,950 ft/sec
	Right 5,700 ft/sec
	Average 5,830 ft/sec

Camera Records:

All smear and Fastax records of launch were good. The evaluation of the photographs gave the following muzzle velocities:

West Fastax (6 in.lens, 160 ft ahead of muzzle) - 6,020 ft/sec

East Fastax (10 in.lens, 140 ft ahead of muzzle) - 6,000 ft/sec

Smear (150 and 200 ft ahead of muzzle) - 5,620 ft/sec.

The Fastax results are approximately 2% to 3% higher than the average probe value of 5,830 and a velocity of 5,900 ft/sec obtained from the radar results. The smear results are considerably lower and probably not reliable.

Radar Records:

Both the M-33 and the MPS-19 radar recorded a normal vehicle flight.

Trajectory:

The radar data were plotted in comparison with the standard trajectory for 5,900 ft/sec muzzle velocity at 82.5 deg launch angle (Figs. 22a to 22c). The range data indicate that the effective launch angle was smaller by 0.5 to 1 deg (81.5 deg - 82 deg).

Fig. 22d shows that the flight was along the gun line. An apogee of 391,000 ft = 119 kilometers was obtained. The estimated total range: 200,000 ft.

Telemetry:

R.F. signals and data were received during the periods 0 to 115, 176 to 196, and 201 to 240 seconds.

Good Langmuir probe data were received, but no magnetometer data.

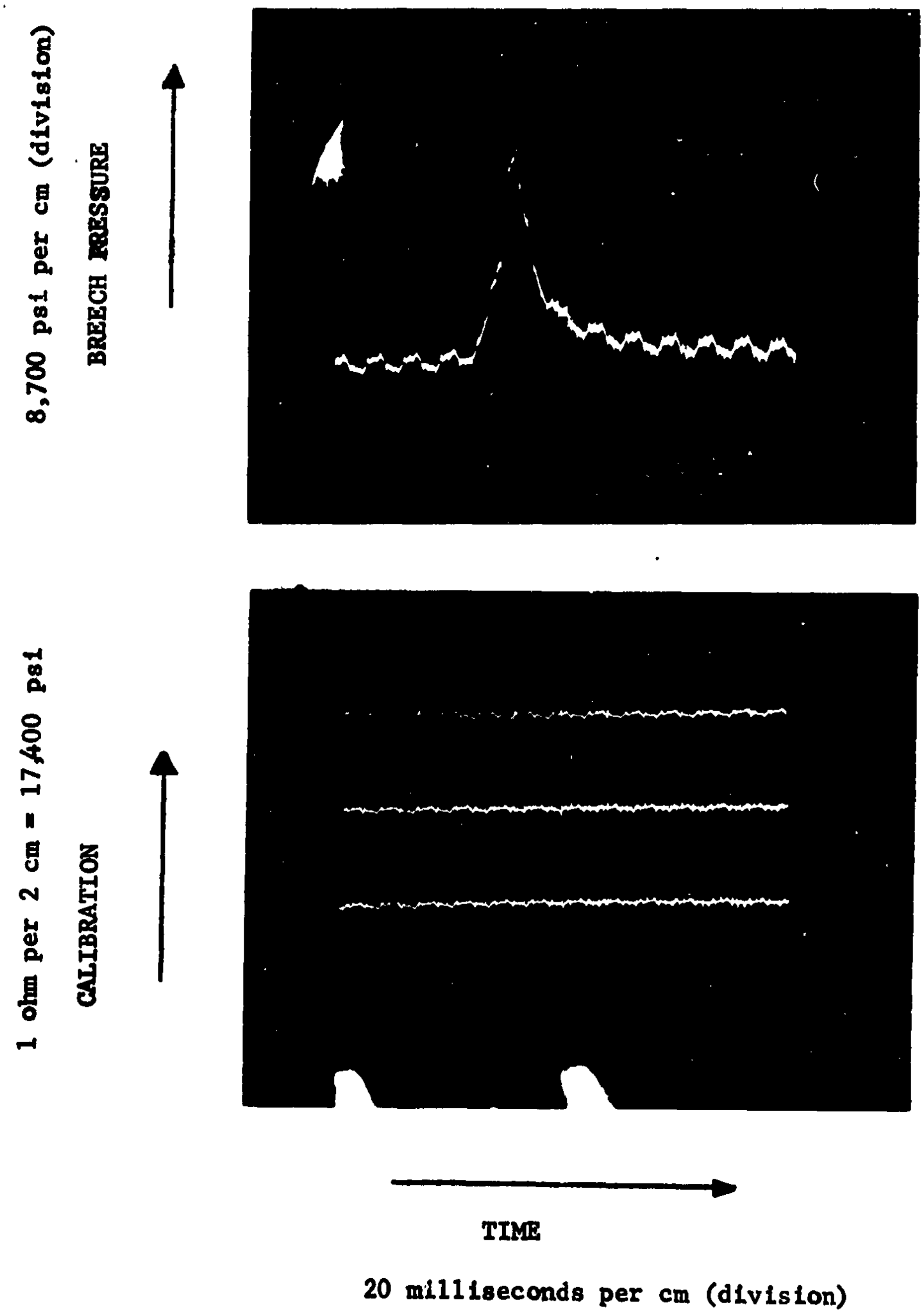
Owing to a relay failure in the GMD-1 tracking antenna, no tracking was accomplished.

Summary:

Successful round with good radar tracking and fair telemetry.

BRUTUS

5 JUNE 1965 - 1620 HR AST



Maximum Breech Pressure: P_{max} = 37,300 psi

Fig. 22 STRAIN GAUGE RECORD OF BREECH PRESSURE ROUND BRUTUS

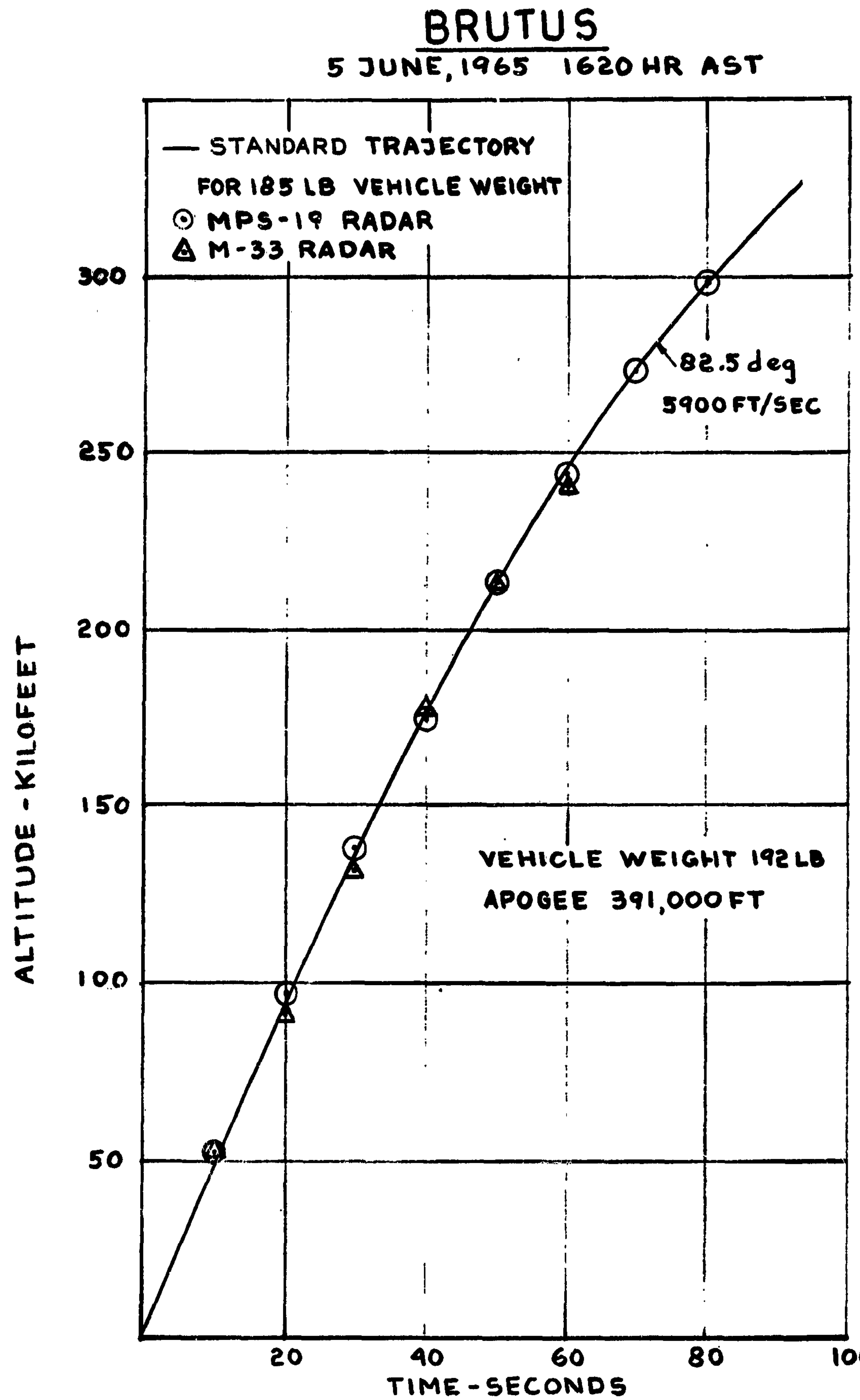


FIG. 22a MARTLET 2C SHOT BRUTUS
ALTITUDE VS TIME

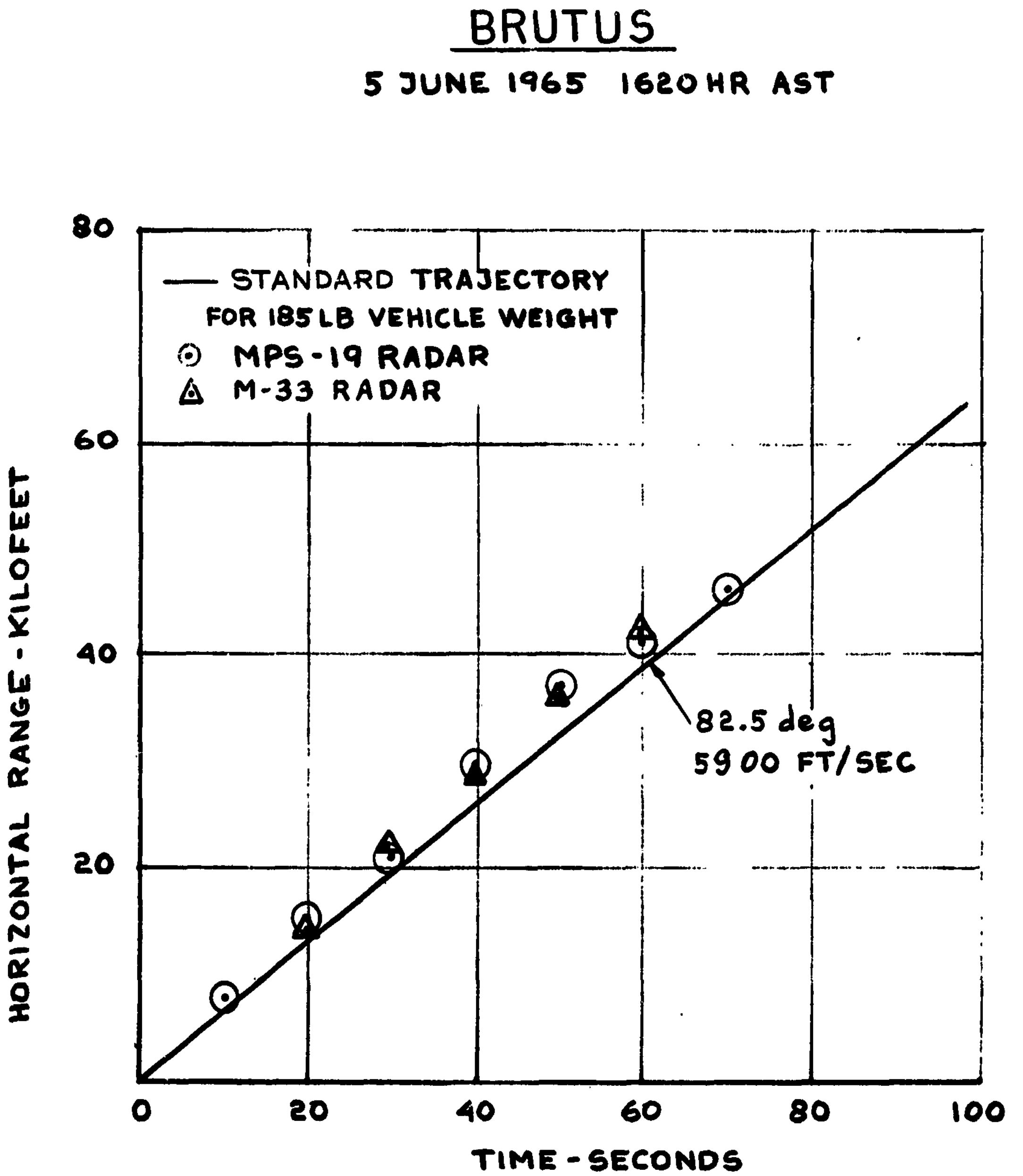


FIG. 22b MARTLET 2C SHOT BRUTUS
RANGE VS TIME

BRUTUS

5 JUNE, 1965 1620 HR AST

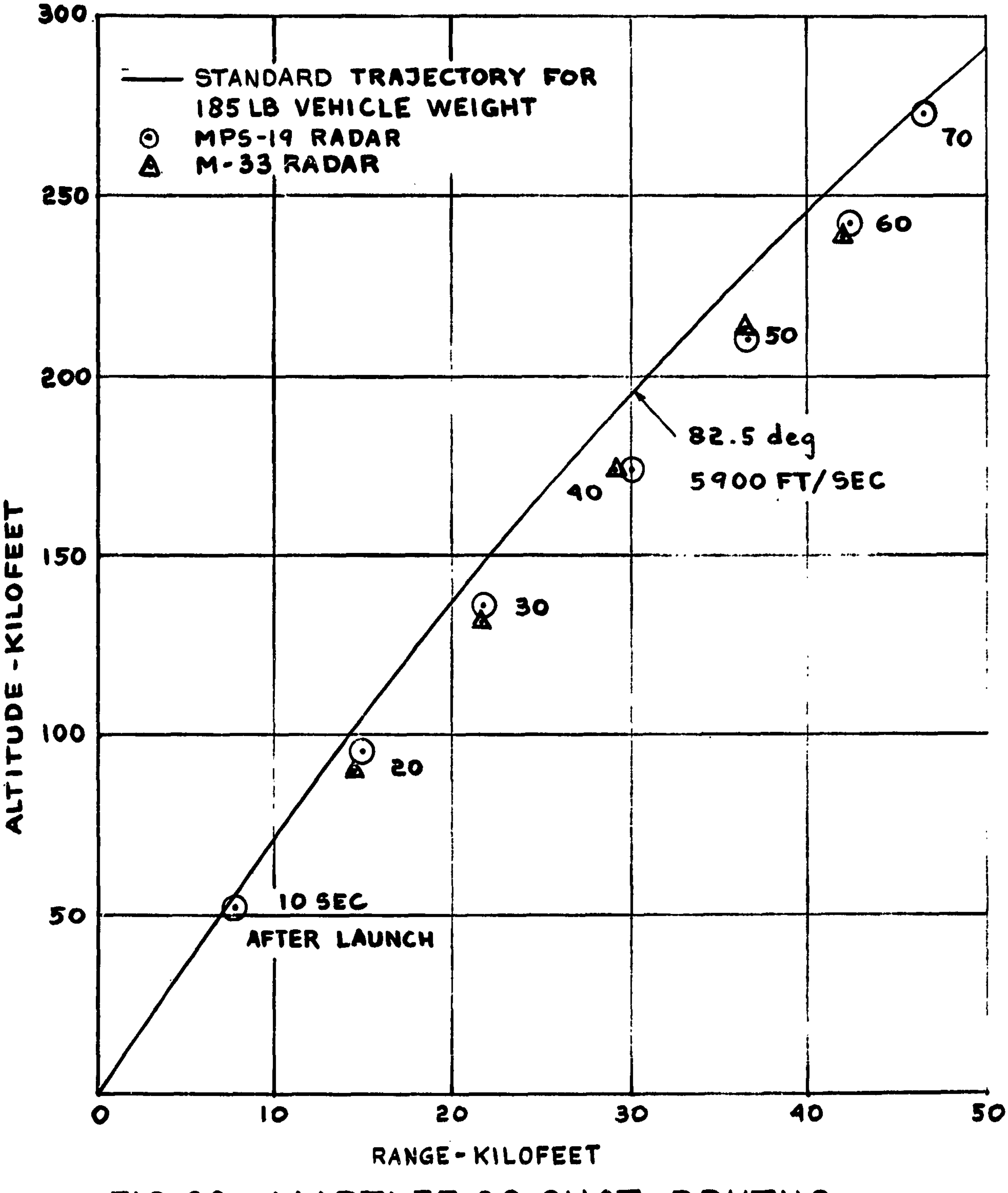


FIG. 22c MARTLET 2C SHOT BRUTUS

ALTITUDE VS RANGE

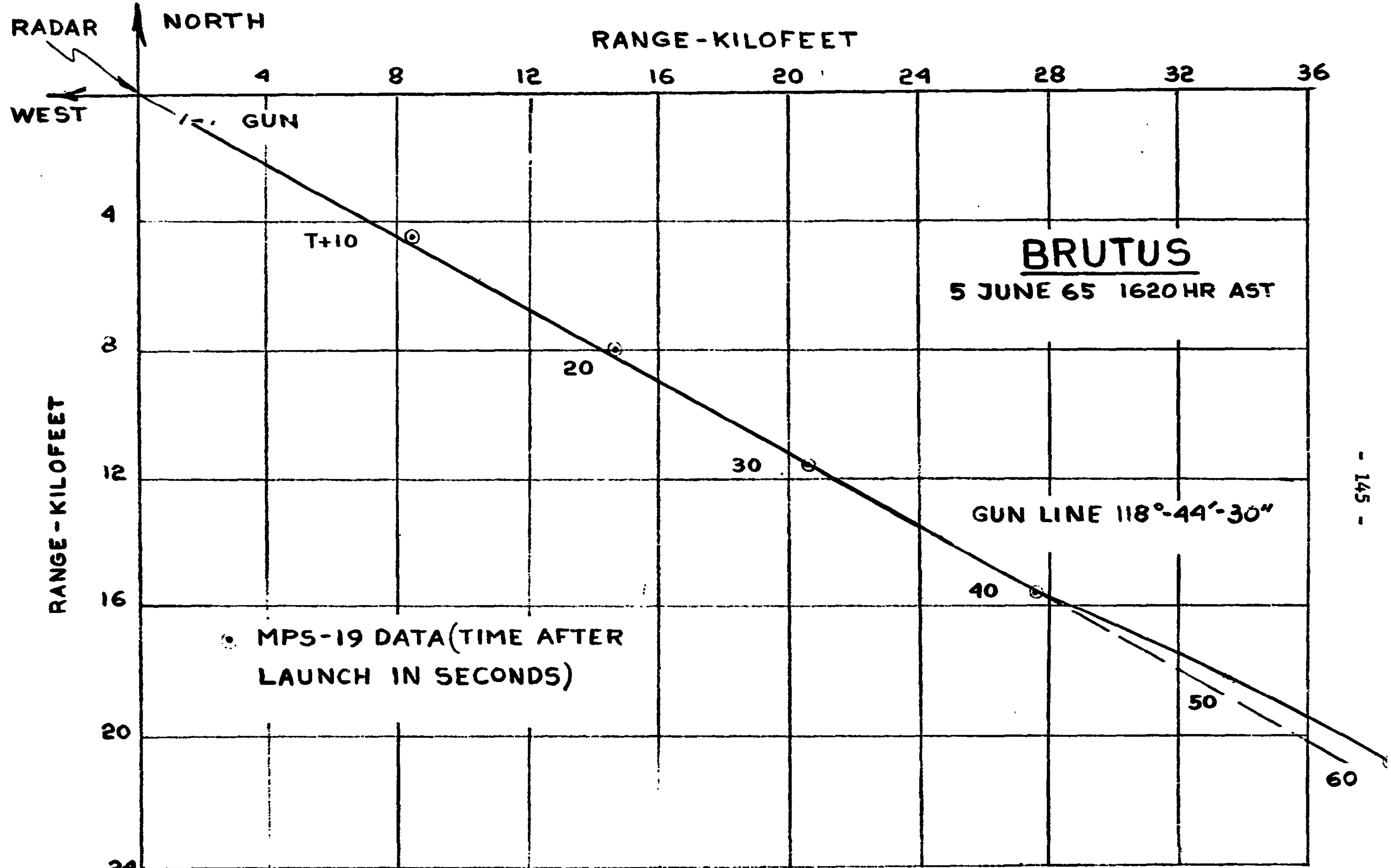


FIG.22d PLAN VIEW OF MARTLET 2C-MODEL BRUTUS TRAJECTORY.

5.5.3 Round No. 12 - JANUS

Date: 5 June, 1965 - 1843 hr A.S.T.

Vehicle Description: Martlet 2C (Mod. 1) carrying an AC Langmuir probe and magnetometer. A 1750 megacycle telemetry was used (BML). See Section 9.2 for details.

Purpose of Test: Electron density measurements at sunset.

Weights:	Vehicle	192.5 lb
	Pusher and Obturator	121.0 lb
	Sabot	103.5 lb
	Shot Weight	417.0 lb

Centre of Gravity: 21.31 in. from base.

Launch Data:

Charge Weight	750 lb M8M (8 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	82.5 degrees
Crusher Gauges	M11 - 4
Ram Distance	189 in
Ram Load	25 tons
Chamber Volume	40,160 in^3
Recoil	37.5 in
Breech Pressure	M11 41,200 psi
	Strain 37,200 psi (Fig. 23)
Muzzle Velocity Probe	left 5,890 ft/sec
	right 5,980 ft/sec

Camera Records:

All camera records were poor owing to lighting conditions.

Radar Records:

Both radars indicated normal vehicle flight.

Trajectory:

The radar results are plotted in Fig. 23a to 23d in comparison with a standard trajectory for 5,900 ft/sec muzzle

velocity and 82.5 deg launch elevation. The agreement is good, The flight was, however, as much as 5 deg off azimuth, as seen in Fig. 23d. The apogee was 386,000 ft = 117 km and the total range was measured as 201,000 ft in good agreement with standard drag trajectory predictions.

Telemetry:

Good R.F. signals and telemetry data were received from 0 to 208 seconds. Telemetry tracking was excellent. However, no Langmuir probe or magnetometer data were received.

The vehicle apogee was obtained at 157 seconds, in good agreement with the data given below.

Summary:

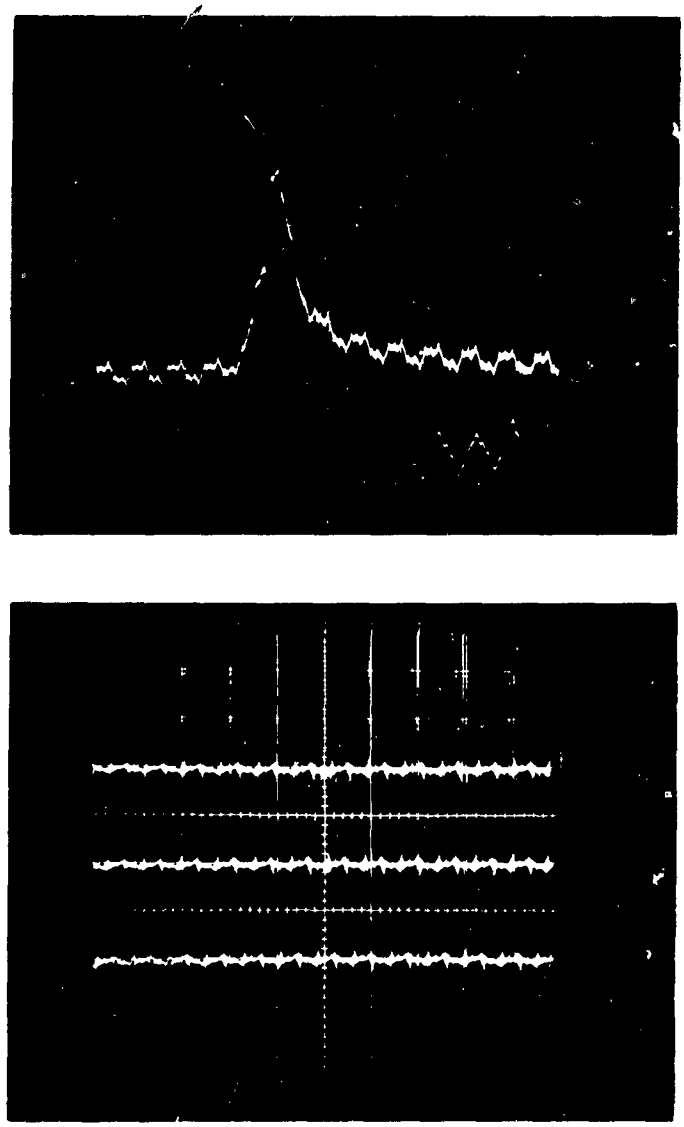
Successful flight with good tracking and telemetry signals. No magnetometer and Langmuir probe data, however, were obtained.

JANUS

5 JUNE 1965 - 1843 HR AST

8,700 psi per cm (division)

BREECH PRESSURE



1 ohm per 2 cm = 17,400 psi

CALIBRATION

TIME

20 milliseconds per cm (division)

Maximum Breech Pressure: Pmax = 37,200 psi

Fig. 23 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND JANUS

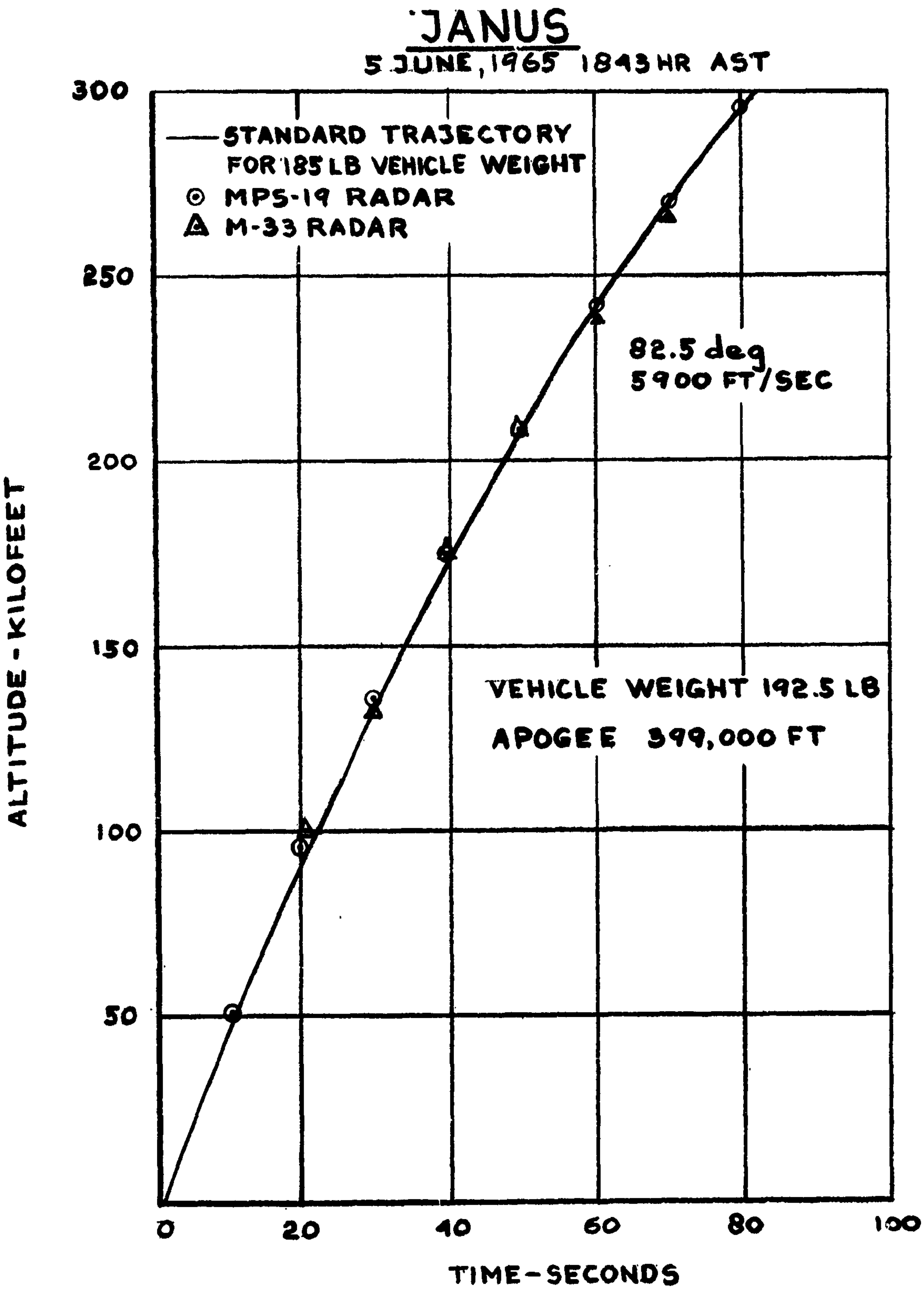


FIG. 23a MARTLET 2C SHOT JANUS

ALTITUDE VS TIME

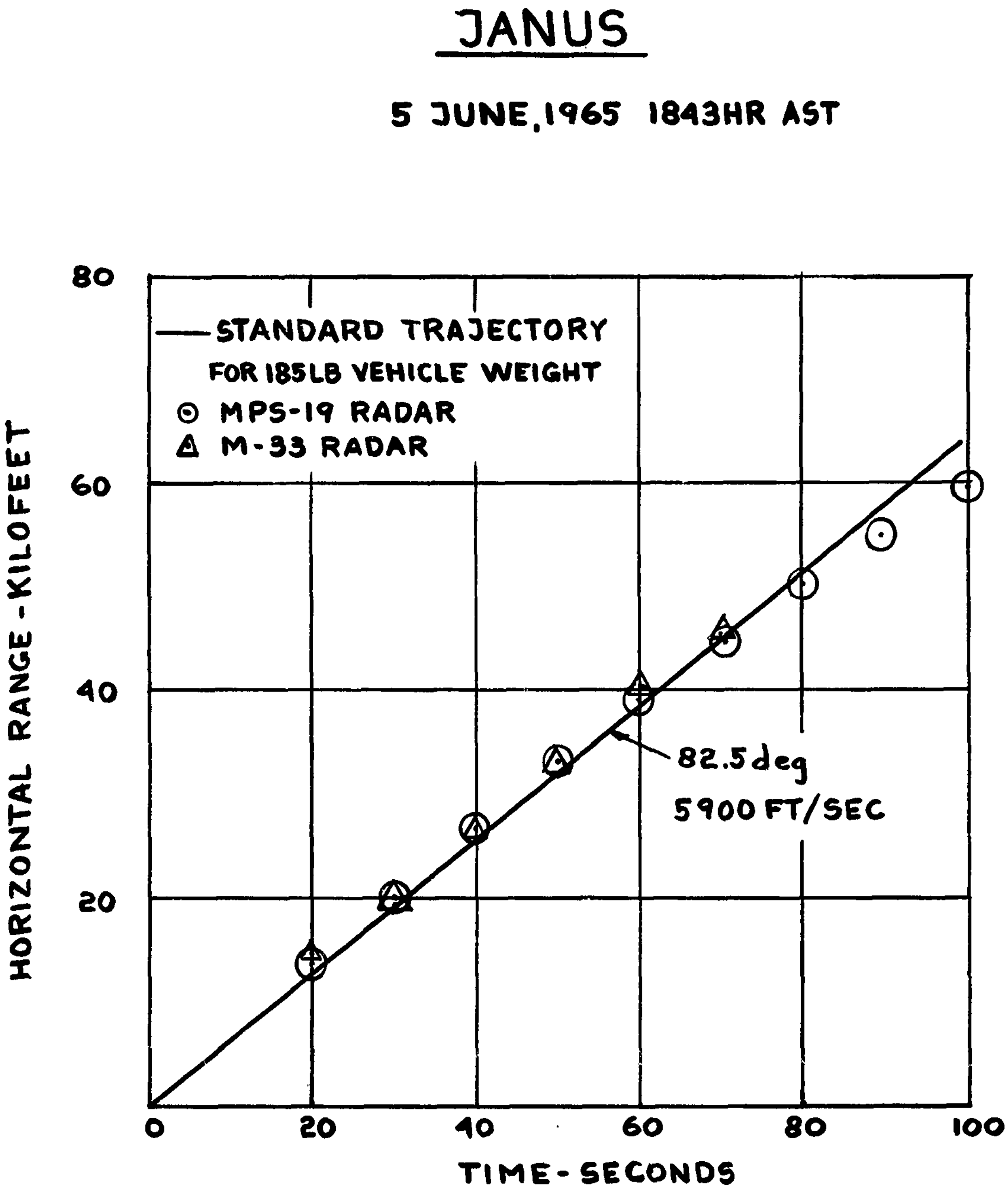


FIG. 23b MARTLET 2C SHOT JANUS

RANGE VS TIME

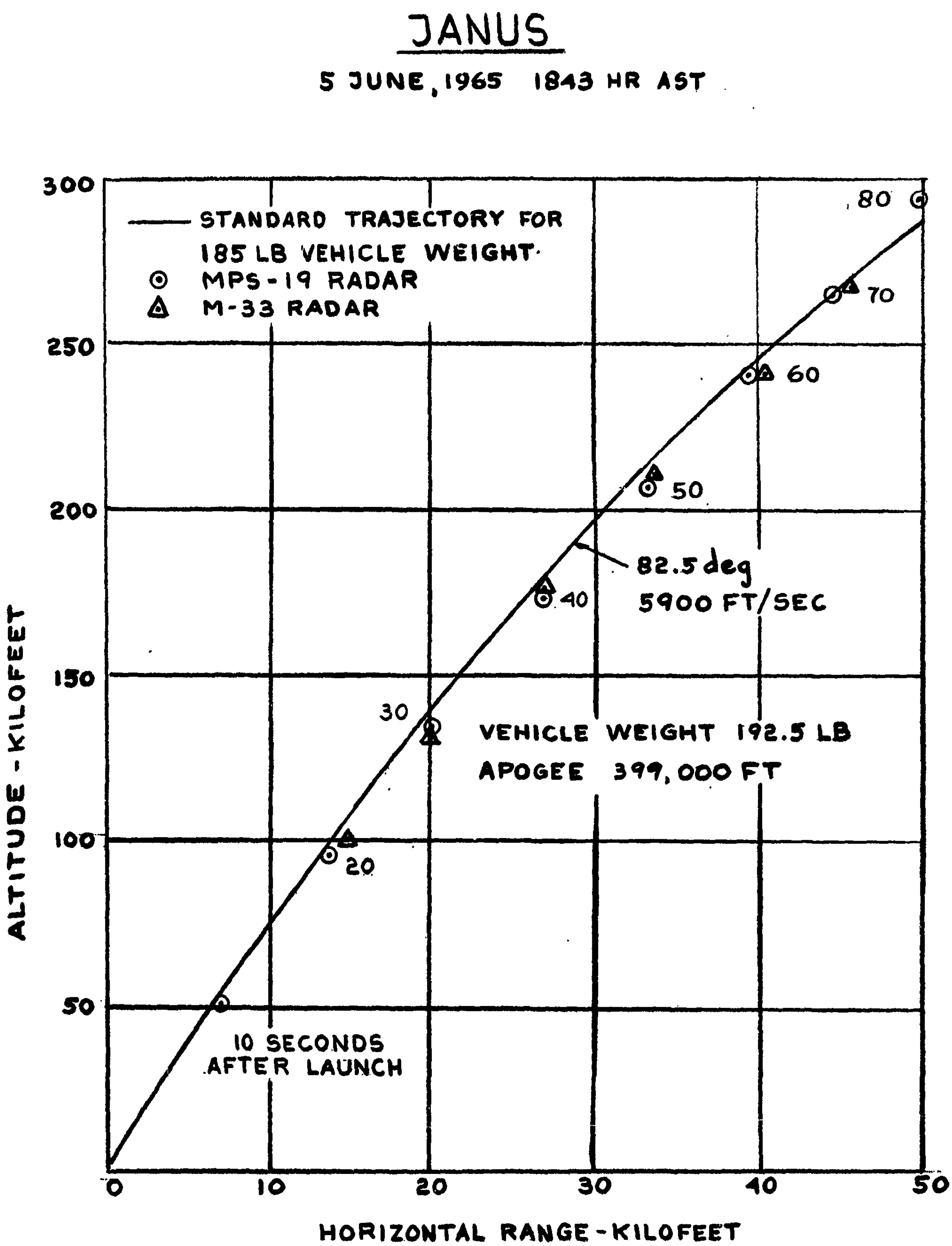


FIG. 23c MARTLET 2C SHOT JANUS
ALTITUDE VS RANGE

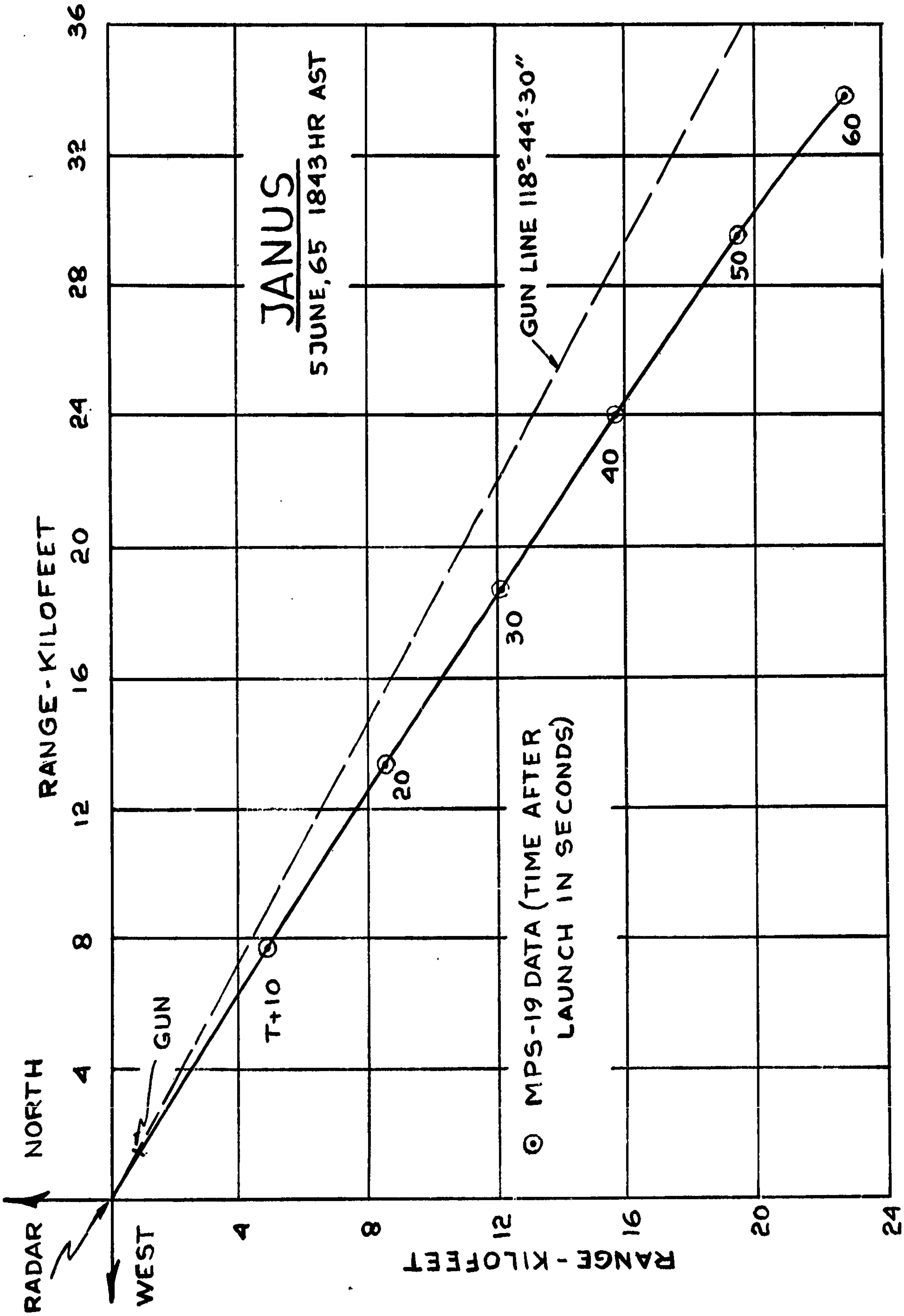


FIG.23 d. PLAN VIEW OF MARTLET 2C - JANUS TRAJECTORY

6.0 THE MARTLET 3B SERIES

6.1 Vehicle

The Martlet 3B vehicle, already proven to be structurally reliable for grain launch tests, was in a configuration similar to that of the steel vehicle used in the March test series (Ref. 1). Schematics of the vehicles with the two different internal grain support configurations are shown in Fig. 24a and Fig. 24b. End burning composite grains, manufactured by Lockheed Propulsion Company, were used in order to test at high launch accelerations (a) the epoxy support technique for an end burning composite grain, and (b) the fluid support technique for a grain within a motor case. The grains were 8 in. in diameter, 40 in. long, and weighed approximately 120 lb. In accordance with the main purpose of the test, no ignition system was provided.

For the first test, the end burning grain was cartridge loaded into the vehicle which was mounted in a vertical position with its nose down. Liquid epoxy was slowly poured into the (approx.) 1/16 in. radial clearance between the grain and the case wall until all voids were filled around the propellant, and an excess of epoxy remained above the end of the grain. The aft closure was slowly screwed down into position and excess epoxy was forced out through a small hole, provided for that purpose, in the closure. A small plug was then assembled to block the "overflow" hole. This process served to ensure a loaded assembly free of voids or air bubbles. The epoxy

was cured to a solid state prior to the launch test.

For the second test, a similar loading procedure was employed. In this case, however, a small amount of liquid epoxy was poured onto the head closure prior to the loading of the grain. The grain was cartridge loaded as in the first assembly and small spacers were inserted to ensure concentricity between the grain and the case. The epoxy was left to cure at room temperature for an adequate time period thereby creating a strong bond between the propellant grain and the head closure. The fluid, a zinc-bromide-water solution, was loaded into the case shortly before launch using a procedure virtually identical to that described for the epoxy loading in the first test. It was previously verified that there was no significant reaction between the propellant and the zinc bromide solution for the time period involved between the fluid loading and launch. The solution was adjusted before loading in order to attain a density slightly higher than that of the propellant.

6.2 Payload

A 60 lb aluminum dummy nose cone representing potential payload capacity was flown on both vehicles of this series.

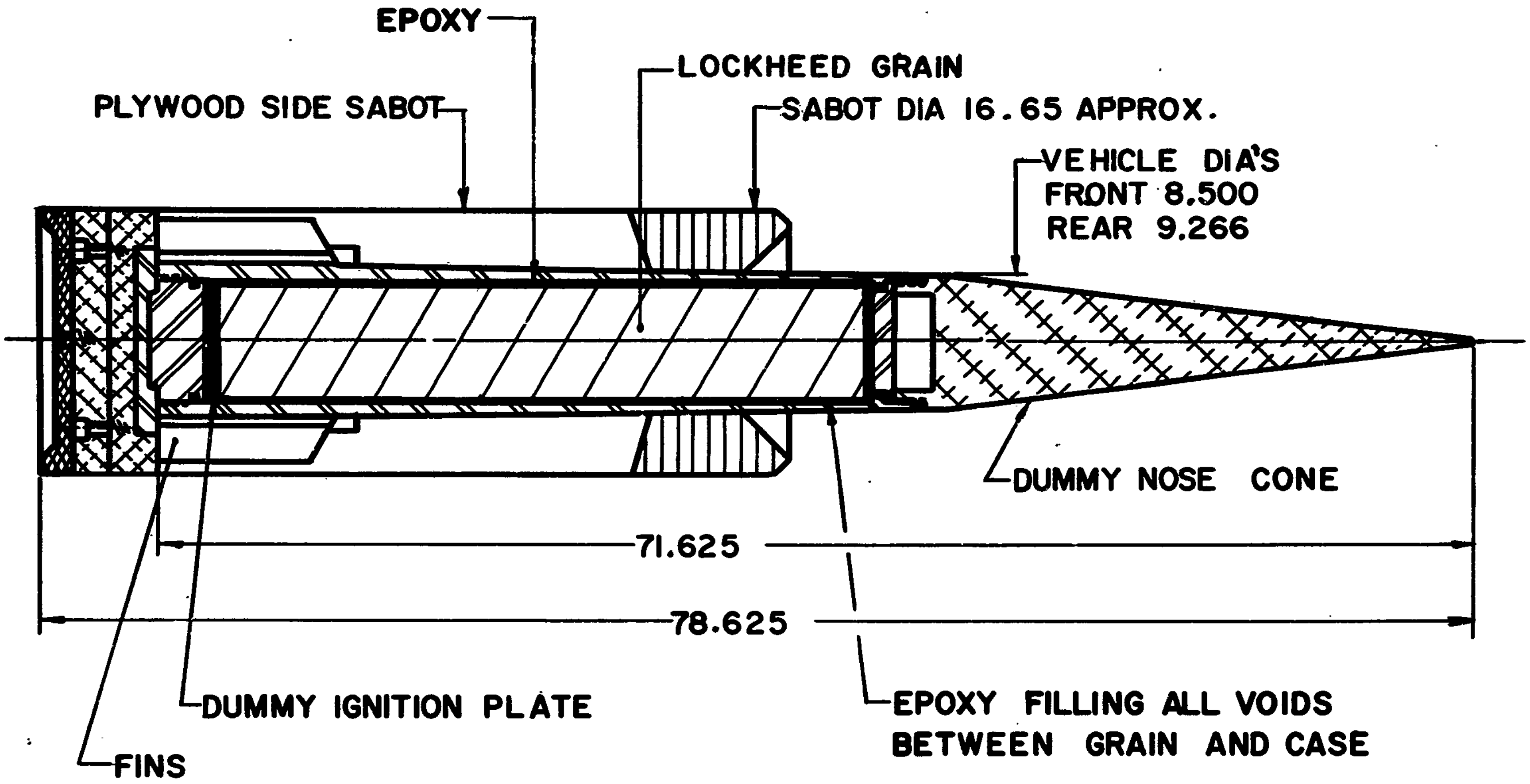
6.3 Firing Program

Two vehicles, DEVILS and EAGLE, were fired in this series using identical charge weights. In each launch a breech pressure of approximately 40,000 psi, a maximum acceleration of approximately 9,000 g, and a muzzle velocity of about 5,100 ft/sec were achieved.

The end-burning propellant configuration supported in the motor chamber by epoxy potting or fluid was found to be satisfactory since both motor cases were launched from the gun intact. The vehicles, however, were stripped of their fins in the barrel during launch. This was of no importance to the experiment since there was no real interest in the trajectory.

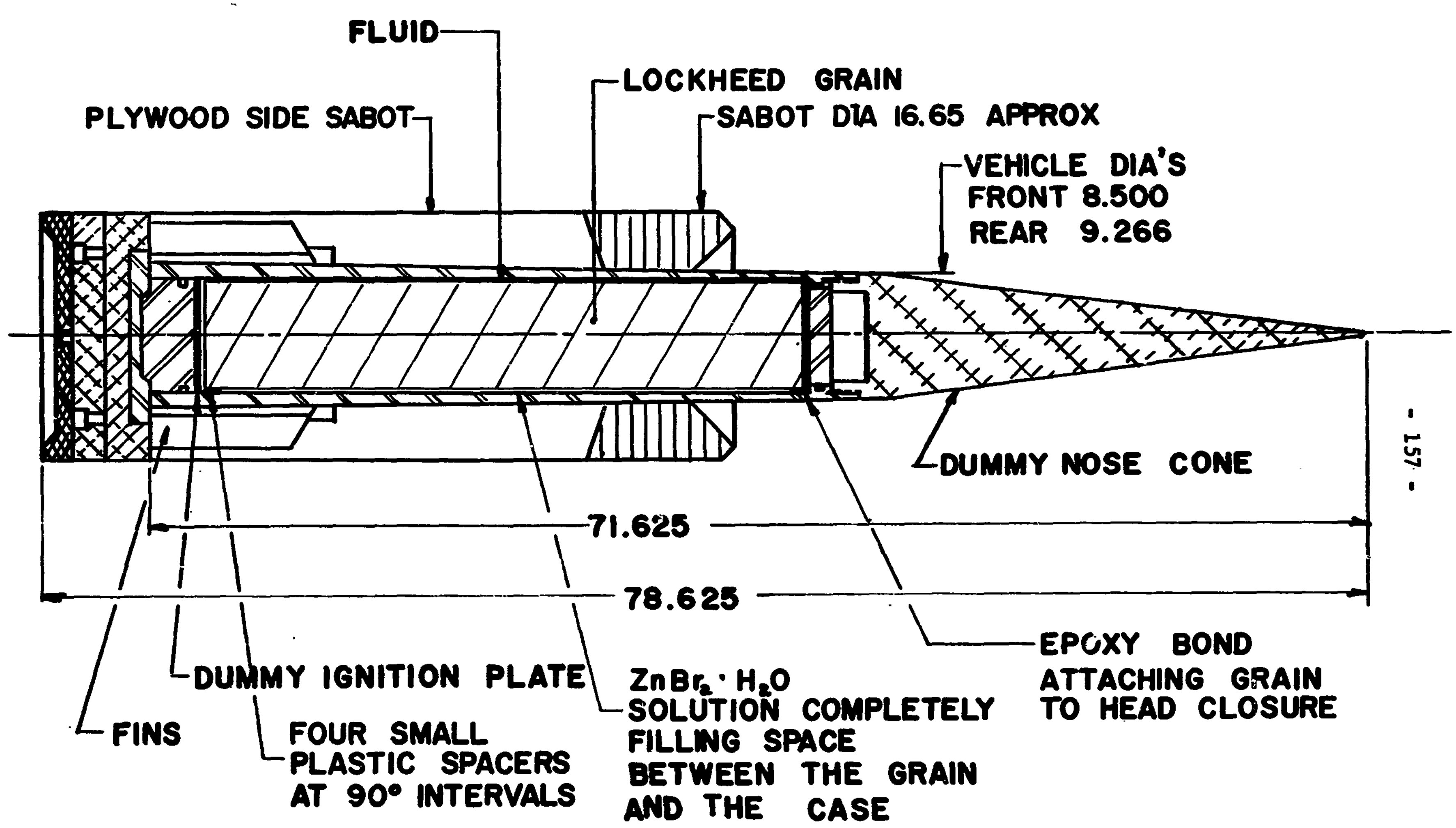
As a result of this instability, the epoxy support test vehicle, DEVILS, was recovered near the gun. This proved to be extremely valuable as it was then possible to carry out a post-firing radiographic inspection of the propellant for cracks and voids. A comparison of these results with the original radiographic plates, taken after casting the propellant, indicated that no additional deformation had taken place during launch. This is positive proof of the ability of relatively large sizes of solid rocket grain to withstand the high accelerations encountered during launch from a gun.

The flight results of the two rounds are summarized in Table V, and the detailed flight performance is discussed in Section 6.4.



MARTLET 3 B LOCKHEED TEST CONFIGURATION #1

FIGURE 24 A



MARTLET 3B - LOCKHEED TEST CONFIGURATION # 2

FIGURE 24 B

TABLE V

MAY/JUNE 1965 TEST PROGRAM - MARTLET 3B SERIES

Flight	Vehicle Description	Weight (lb)	Launch Data	Breech Pressure (psi)	Muzzle Velocity (ft/sec)	Apogee ft(km)	Comments
3 (110) DEVILS 3/6/65 1432 hr AST QE 86 deg	Martlet 3B de-stabilized airframe carrying an 8 in. diameter Lockheed composite grain potted in the case by epoxy.	Wv: 368 Ws: 606.2 C: 675 (M8M)	RD: 186 in RL: 100 tons ChV: 39,520 in^3 Rec: 41.3 in	St: 37,400 Mk6: } 41,100 M11: }	P: 6760 5090 - R: - EF: 5130 WF: 5180 S: 5220	-	Test was successful since the rocket grain survived a launch acceleration of over 9000 g. The vehicle lost all fins during acceleration in the barrel.
13 (120) EAGLE 7/6/65 1211 hr AST QE 82.5 deg	Martlet 3B de-stabilized airframe carrying an 8 in. diameter Lockheed composite grain and an 8 to 10 second tracer. The grain was bonded to the head closure by epoxy and fluid supported.	Wv: 372.0 Ws: 611.25 C: 675 (M8M)	RD: 188.25 in RL: 50 tons ChV: 40,000 in^3 Rec: 39.0 in	St: 34,000 M11: 37,900	P: 5150 - - R: - EF: 5120 WF: 5090	-	The fluid supported rocket grain also survived the launch. Fins were again stripped from the vehicle.

Wv: Vehicle Weight
Ws: Shot Weight
C: Charge Weight

RD: Ram Distance
RL: Ram Load
ChV: Chamber Volume
Rec: Recoil

St: Strain Gauge
Mk6: } Crusher Gauges
M11: }

P: Probe 1st Fig. Left
2nd Fig. Right
3rd Fig. Average
R: Radar
WF: West Fastax
EF: East Fastax
S: Double Smear

6.4 Detailed Flight Performance

6.4.1 Round No. 3 - DEVILS

Date: 3 June, 1965 - 1432 hr A.S.T.

Vehicle Description: Martlet 3B de-stabilized airframe carrying an 8 in. diameter Lockheed composite grain potted in the case by epoxy.

Purpose of Test: To check the structural integrity of end-burning type rocket grain using the epoxy potting technique under high launch accelerations.

Weights:	Vehicle	368.0 lb
	Pusher and Obturator	139.1 lb
	Sabot	99.0 lb
	Shot Weight	606.3 lb

Centre of Gravity: 24.4 in. from base.

Launch Data:

Charge Weight	675 lb M8M (7 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	86 degrees
Crusher Gauges and Coppers	M11 - 4 Mk6 - 4
Ram Distance	186 in
Ram Load	100 tons
Chamber Volume	39,520 in^3
Recoil	41.3 in
Breech Pressure	M11, Mk6: 41,100 psi (average) Strain 37,400 psi (Fig. 25)
Muzzle Velocity Probe	left 6,760 ft/sec right 5,090 ft/sec

Camera Records:

Fastax and smear recorded useful launch data. The evaluation of photographs gave the following muzzle velocity values:

West Fastax (6 in. lens, 160 ft ahead of muzzle) - 5,180 ft/sec

East Fastax (10 in.lens, 140 ft ahead of muzzle) - 5,130 ft/sec

Double Smear (150 and 200 ft ahead of muzzle) - 5,220 ft/sec.

All launch photographs showed that the fins were stripped in the barrel, but that the case and grain were launched intact.

Radar Records:

No records.

Recovery:

The airframe was recovered on land near the East Fastax station, inside the safety area.

Summary:

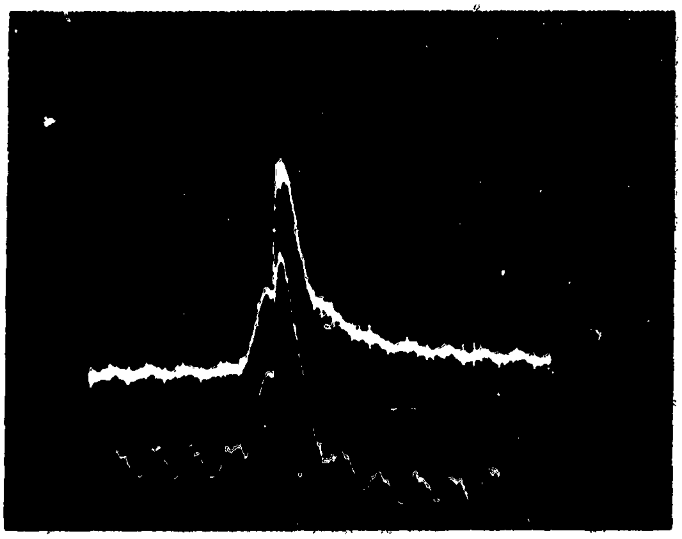
The test was successful since the rocket grain survived a launch acceleration of 9,200 g, without any permanent deformation as shown by radiographic inspection.

DEVILS

3 JUNE 1965 - 1432 HR AST

8,700 psi per cm (division)

BREECH PRESSURE



TIME

20 milliseconds per cm (division)

Maximum Breech Pressure: Pmax = 37,400 psi

Fig. 25 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND DEVILS

6.4.2 Round No. 13 - EAGLE

Date: 7 June, 1965 - 1211 hr A.S.T.

Vehicle Description: Martlet 3B de-stabilized airframe carrying an 8 in. diameter solid Lockheed composite grain and an 8 to 10 second tracer. The grain was fluid supported in the case.

Purpose of Test: To check the structural integrity of an end-burning type rocket grain, using the fluid support technique, under high launch accelerations.

Weights:	Vehicle	372.0 lb
	Pusher and Obturator	140.8 lb
	Sabot	98.5 lb
	Shot Weight	611.3 lb

Centre of Gravity: 24.5 in. from base.

Launch Data:

Charge Weight	675 lb M8M (7 bags)
Swedish Additive	15 sheets
Igniter	500 grams/bag
Gun Elevation	82.5 degrees
Crusher Gauges	M11 - 4
Ram Distance	188.3 in
Ram Load	50 tons
Chamber Volume	40,000 in^3
Recoil	39 in
Breech Pressure	M11 37,900 psi
	Strain 34,000 psi (Fig. 26)
Muzzle Velocity Probe	left 5,150 ft/sec

Camera Records:

All Fastax and smear cameras gave useful data. The evaluation of photographs resulted in the following muzzle velocity values:

West Fastax (6 in. lens, 160 ft ahead of muzzle) - 5,090 ft/sec

East Fastax (10 in. lens, 140 ft ahead of muzzle) - 5,130 ft/sec.

Radar Records:

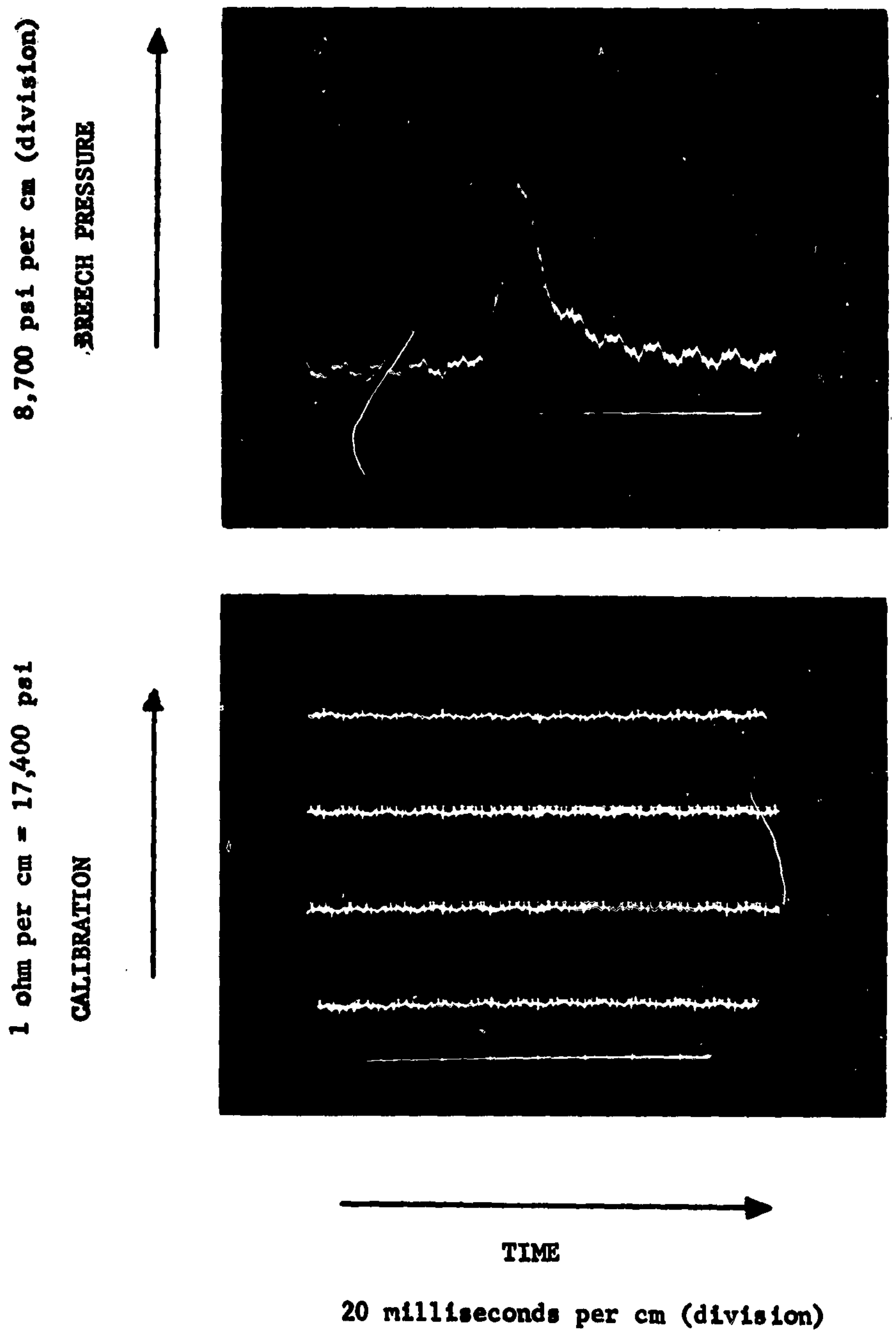
No records.

Summary:

The round was similar to DEVILS. The vehicle was launched with fins stripped but otherwise the launch was normal, and the rocket grain survived a launch acceleration of 8,700 g.

EAGLE

7 JUNE 1965 - 1311 HR AST



Maximum Breech Pressure: Pmax = 34,000 psi

Fig. 26 STRAIN GAUGE RECORD OF BREECH PRESSURE
ROUND EAGLE

7.0 ANALYSIS OF TEST RESULTS

7.1 Muzzle Velocity Data

Muzzle velocity data were obtained by muzzle probes, Fastax and smear photographs, and from the radar trajectories with the assumption of standard drag.

A summary of all results is presented in Table VI. Muzzle probe data with a difference of more than 5 percent ($\pm$ 2.5 percent) between the left and the right probes are regarded as unsatisfactory; this is the case in almost 50 percent of the rounds. For this reason the velocities obtained from the Fastax photographs are thought to be more reliable.

The velocities given in the table as radar results refer to standard drag trajectories as discussed in Section 2.2.

TABLE VI - MUZZLE VELOCITY DATA

F: Fastax
P: Probe
R: Radar

Velocities in ft/sec

Shot No.	Name	Vehicle	Shot Wt (lb)	Charge Wt (lb)	MV PROBE Left	MV PROBE Right	MV PROBE Av	MV PROBE Spread %	FASTAX East	FASTAX West	FASTAX Av	Double Smear	Radar	Chosen Vel.
1	APPIUS	2A	420	630	5000	5020	5010	± 0.2	5120	5150	5130	4760	5000	5130 F
2	RUFUS	2A	425	585	4850	4860	4860	± 0.2	4870	4900	4880	4550	4900	4880 F
3	DEVILS	3B	606	675	6760	5090	Unsatisfactory		5130	5180	5160	5210	-	5160 F
4	IRE	2C Mod. 1	420	725		Data Useless			5880	5910	5890	-	-	5890 F
5	MARIUS	2C	413	725	4860	5950	Unsatisfactory		-	-	-	-	5700	5700 R
6	NERO	2C	412	725	6200	4800	Unsatisfactory		-	-	-	-	5300	?
7	ELAGABULUS	2C	415	735	5750	6090	5920	± 2.9	-	-	-	-	5900	5920 P
8	FABIUS	2C	414	745	5130	-	Unsatisfactory		-	-	-	-	5620	5620 R
9	GRACCHUS	2C	415	750	6460	7050	Unsatisfactory		-	5810	-	-	5750	5810 F
10	SPARTA	2A	416	600	4660	4570	4620	± 1.0	-	4860	-	-	4800	4860 F
11	BRUTUS	2C Mod. 1	419	750	5950	5700	5830	± 2.2	6000	6020	6010	5620	5900	6010 F
12	JANUS	2C Mod. 1	417	750	5890	5980	5940	± 0.8	-	-	-	-	5900	5940 P
13	EAGLE	3B	611	675	5150	-	-	-	5130	5090	5110	-	-	5110 F
14	LUCRETIA	2C	415	750	6060	6270	6160	± 1.7	-	-	-	-	5900	6160 P
15	OVID	2C	414	750	6080	6150	6120	± 0.6	-	-	-	-	5500	6120 P
16	CICERO	2C	418	760	5930	5970	5950	± 0.3	-	-	-	-	5600	5950 P
17	DIANA	2C	417	780	5170	5910	Unsatisfactory		-	-	-	-	5700	?
18	PLINY	2C	415	780	6850	6140	Unsatisfactory		-	-	-	-	6100	6100 R
19	QUINTUS	2C	416	790	6060	6050	6060	0	-	-	-	-	6150	6060 P

7.2 Maximum Breech Pressure

Pressure data were obtained as usual, by crusher gauges (Mk6 and M11) and by a "Hat" strain gauge in the spindle of the breech as described in Reference 1.

The resulting data are given in Table VII for all shots of this series. It is remarkable that the strain gauge data are in all cases smaller than the crusher gauge results. While in the March test series the strain gauge results were considered to be the most reliable, this is not the case in this series because the pressure curves obtained exhibit considerable noise, and only average values were used for calibration. For this reason, the average crusher gauge values have been taken as representing the actual maximum breech pressure.

TABLE VII

JUNE 1965 TEST SERIES

MAXIMUM BREECH PRESSURES (PSI)

No.	Name	Vehicle	Charge Wt (lb)	Shot Wt(lb)	Mk6	M11	Average Mk6 & M11	Strain
1	APPIUS	2A	630	420	24,900	25,600	25,250	22,600
2	RUFUS	2A	585	425			21,500	20,500
3	DEVILS	3B	675	606			41,100	37,400
4	IRE	2C Mod.1	725	420		40,300	40,300	35,600
5	MARIUS	2C	725	413		37,500	37,500	33,000
6	NERO	2C	725	412		37,700	37,700	34,800
7	ELAGABULUS	2C	735	415		36,700	36,700	35,600
8	FABIUS	2C	745	414		37,500	37,500	36,500
9	GRACCHUS	2C	750	415		38,300	38,300	36,500
10	SPARTA	2A	600	414		20,500	20,500	20,500
11	BRUTUS	2C Mod.1	750	419		41,200	41,200	37,300
12	JANUS	2C Mod.1	750	417		41,200	41,200	37,200
13	EAGLE	3B	675	611		37,900	37,900	34,000
14	LUCRETIA	2C	750	415	38,000	38,900	38,500	36,500
15	OVID	2C	750	414	36,900	38,500	37,700	34,800
16	CICERO	2C	760	418		39,800	39,800	35,200
17	DIANA	2C	780	417		46,300	46,300	43,200
18	PLINY	2C	780	415	46,500	44,800	45,700	41,800
19	QUINTUS	2C	790	416	45,700	49,300	47,500	45,200
20	HADRIAN	2C	780	418	42,100	44,100	43,100	40,000

7.3 Gun Ballistic Performance with M8M.220 Propellant

The breech pressure and muzzle velocity data obtained for various firing conditions give an indication of the ballistic performance of the gun with the propellant chosen for the firing.

In the March test firing series (Ref. 1) the M8M.220 propellant was used, and the test data for breech pressure and muzzle velocity available enabled the establishment of empirical curves for breech pressure and muzzle velocity for various charge weights. The number of test points was small; in the present test series, however, the M8M.220 propellant was used again, and this provided the opportunity to check the former results.

The firing conditions cannot be expected to be the same for all shots. Ram load, ram distance, and consequently the chamber volume will vary from shot to shot. In order to obtain a good comparison of the test data, it is advisable to obtain values of the results corrected for "standard" conditions. This standard condition was chosen to be 50 tons ram load and 40,000 cu. in. chamber volume. In addition, a weight correction was applied, using a "standard" shot weight of 400 lb for the Martlet 2C and 600 lb for the Martlet 3B.

The empirical corrections for breech pressure were given in Ref. 1 as follows:

$$\Delta P_{Br} \approx -\frac{P_{Br}}{40\,000} \times \Delta Vol.$$

$$\Delta P_{Br} \approx \frac{C}{15} \times \Delta R$$

where P_{Br} = breech pressure in psi

C = charge weight in lb

ΔR = change in ram load in tons

ΔVol = change in chamber volume in in^3.

In Ref. 1, no corrections were made of the muzzle velocity because of the relatively small changes involved; for the present series, however, velocity corrections were also used by the following empirical relation:

$$\frac{\Delta V}{V} \approx \frac{1}{4} \frac{\Delta P_{Br}}{P_{Br}} \qquad \text{(at a given weight)}$$

where V is the muzzle velocity in ft/sec.

Corrections for weight changes are relatively small. Note that pressure increases with shot weight (for a given charge weight), whereas the muzzle velocity decreases. The changes depend slightly on the charge weight; however, an average correction (for C = 750 lb) is

ΔP_{Br} = 45 psi/lb shot weight

ΔV = - 4 ft/sec/lb shot weight.

The pressure data used for the analysis are the average crusher gauge results as already explained in Section 7.2. Regarding the muzzle velocities, the Fastax data have been taken, wherever available, as being the most reliable, and in their absence the muzzle probe data are taken. It must bc kept in mind that the

muzzle velocity data obtained from the radar trajectory are based on the assumption of a standard drag and are ambiguous, unless some information on the angle of attack history of the vehicle is available so that an individual drag estimate can be made. Where no other velocity data were available, the radar data have been included in the charts; however they have been marked with an R (radar) as a cautionary measure.

Figure 27 presents the breech pressure as a function of the charge weight, with both test data and data corrected for standard condition and weight. The full lines give the curves as obtained in Ref. 1, the broken line resulting from a computer study of the internal ballistic of M8M.220 in the 16.4 in. gun. It can be seen that the corrected data are equally well represented by the two curves.

Figure 28 shows the muzzle velocities vs charge weight using empirical curves* obtained from the March firings and corrections applied as given above. Note that the Fastax data are in excellent agreement with the empirical curve, whereas some probe data (marked P) show differences.

Figure 29 shows the relation between muzzle velocity and breech pressure, while Figure 30 represents a chart for the ballistic performance of M8M.220 for different shot weights and charge weights.

---

* The curve in Ref. 1 has been changed slightly to account for the velocity corrections.

In general, it can be said that the M8M.220 performance is not optimum; this is indicated by the pressure time diagrams shown for the individual shots, which all exhibit a high pressure peak.

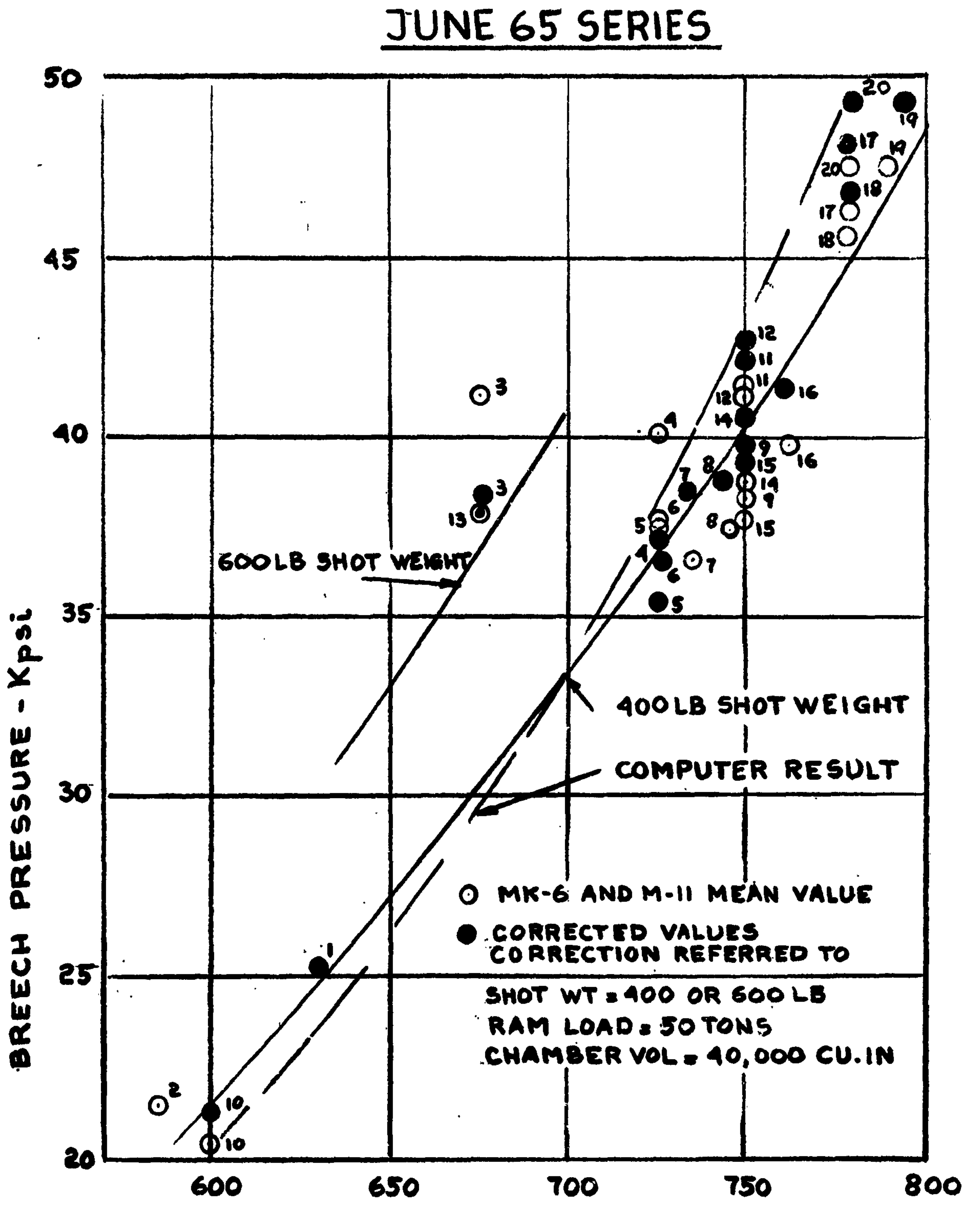


FIG. 27 BREECH PRESSURE VS CHARGE WEIGHT

JUNE 1965 SERIES

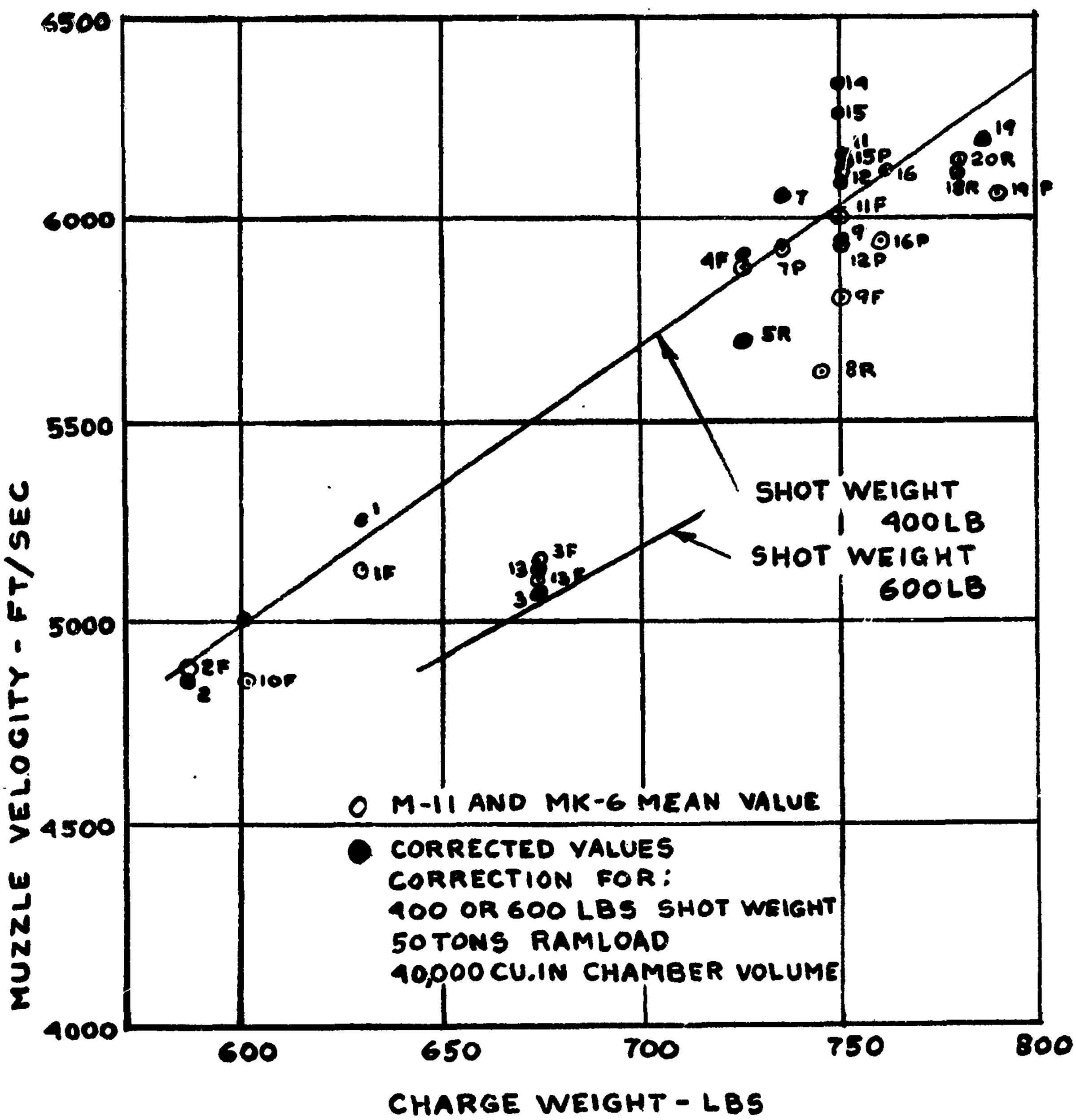
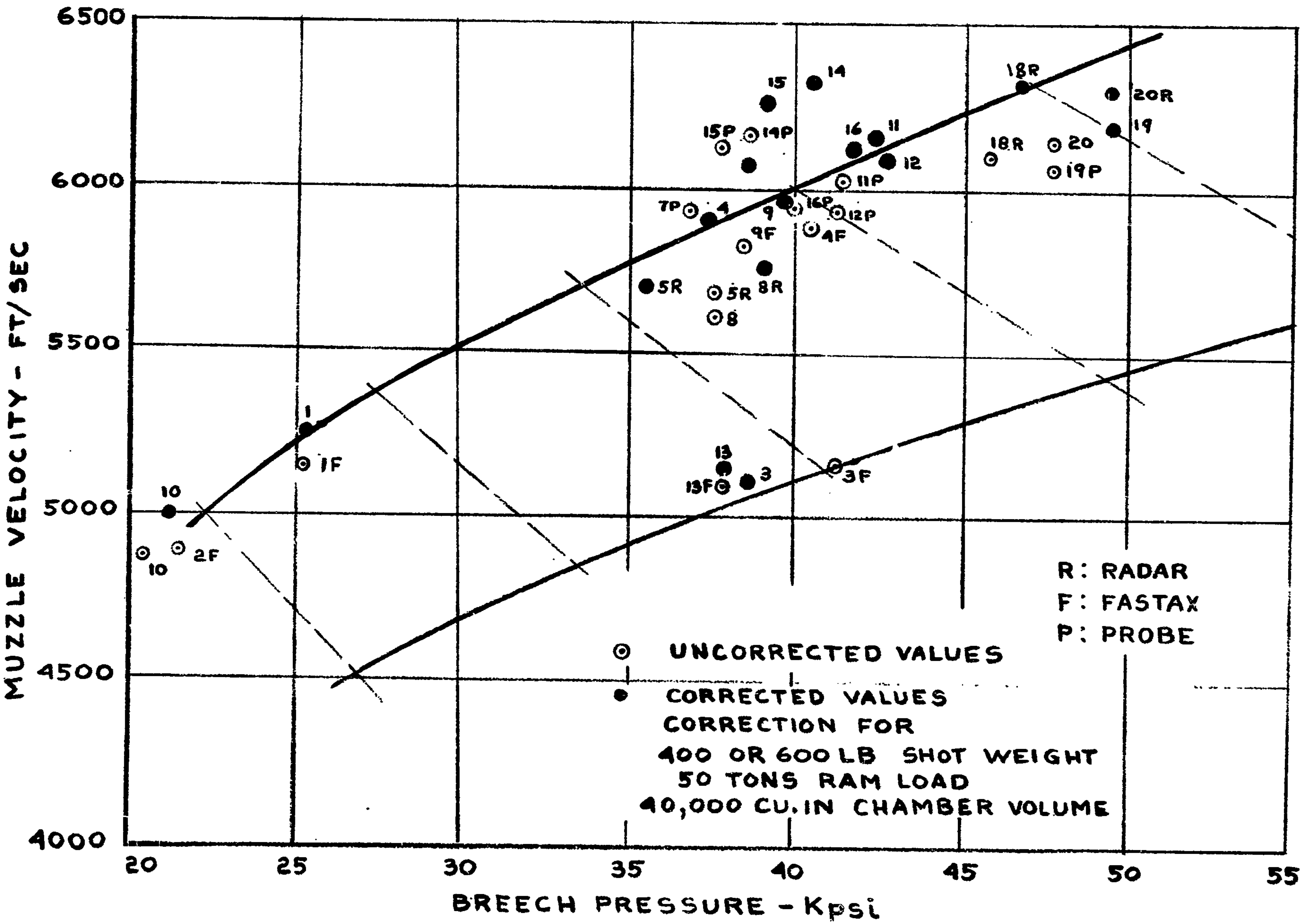


FIG.28 MUZZLE VELOCITY VS CHARGE WEIGHT

16.4" GUN WITH 51 FT MUZZLE EXTENSION



MUZZLE VELOCITY - FT/SEC

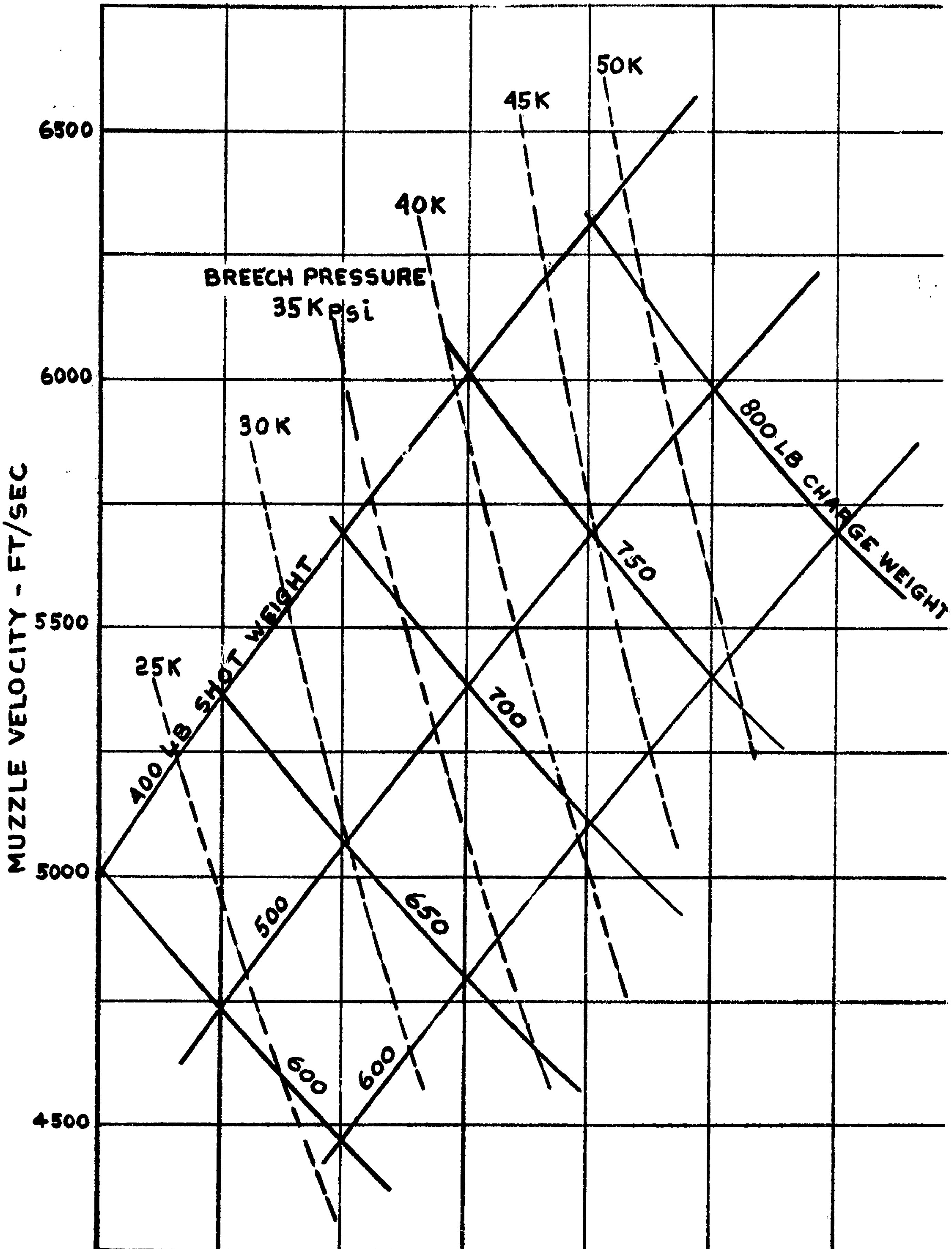


FIG. 30 BALLISTIC PERFORMANCE OF M8M-220-PROPELLANT IN GUN WITH 51FT EXTENSION

8.0 PHOTOGRAPHIC TRIANGULATION OF TMA RELEASE ROUNDS AND WIND SHEAR DATA

Although photographic coverage with the K-24 cameras was somewhat reduced by very bad weather conditions during the series, useful trail photographs were obtained and analyzed. As examples, three trail photographs of the ELAGABULUS round are shown in Figs. 31a to 31c; all three photographs were taken at the same station (St. Vincent North) and at 150, 240, and 402 seconds after launch; thus they demonstrate the change of the trail with time.

The analysis was undertaken by Space Instruments Research and the results were given in Ref. 2 for the seven rounds: MARIUS, NERO, ELAGABULUS, FABIUS, OVID, CICERO, and PLINY. For each of the seven rounds, a data table (Tables VIII to XIV) and graphs (Figs. 32 to 38) are given. The data include wind heading (in degrees, clockwise from North) and wind velocity (meters/second); these data also determine the wind components N-S and E-W, with the directions towards N and E taken as positive. In addition, wind shear components have been derived from the plots.

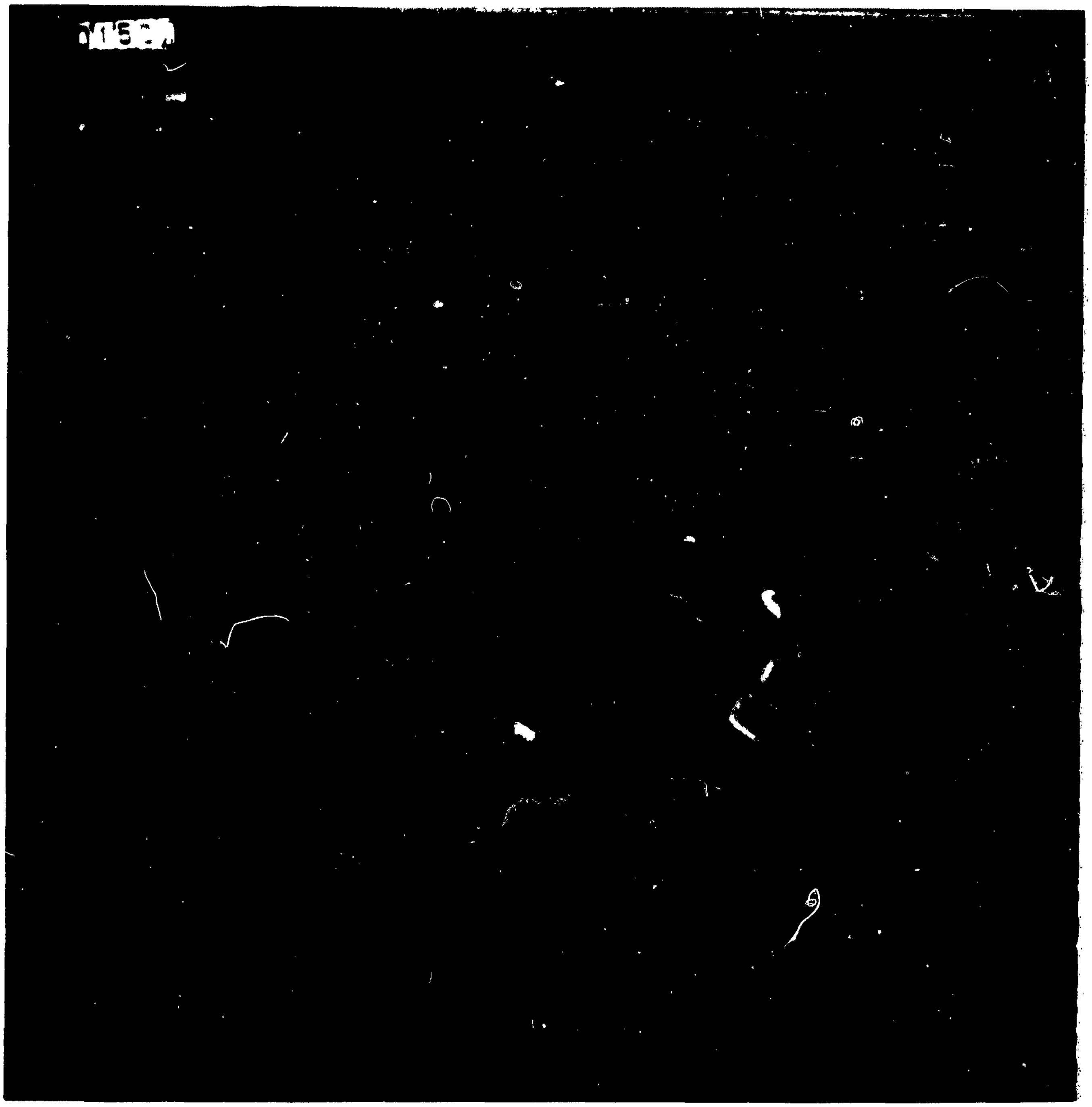


FIG. 31a - ROUND ELAGABULUS

TMA TRAIL

150.4 sec after launch

Station: St. Vincent North

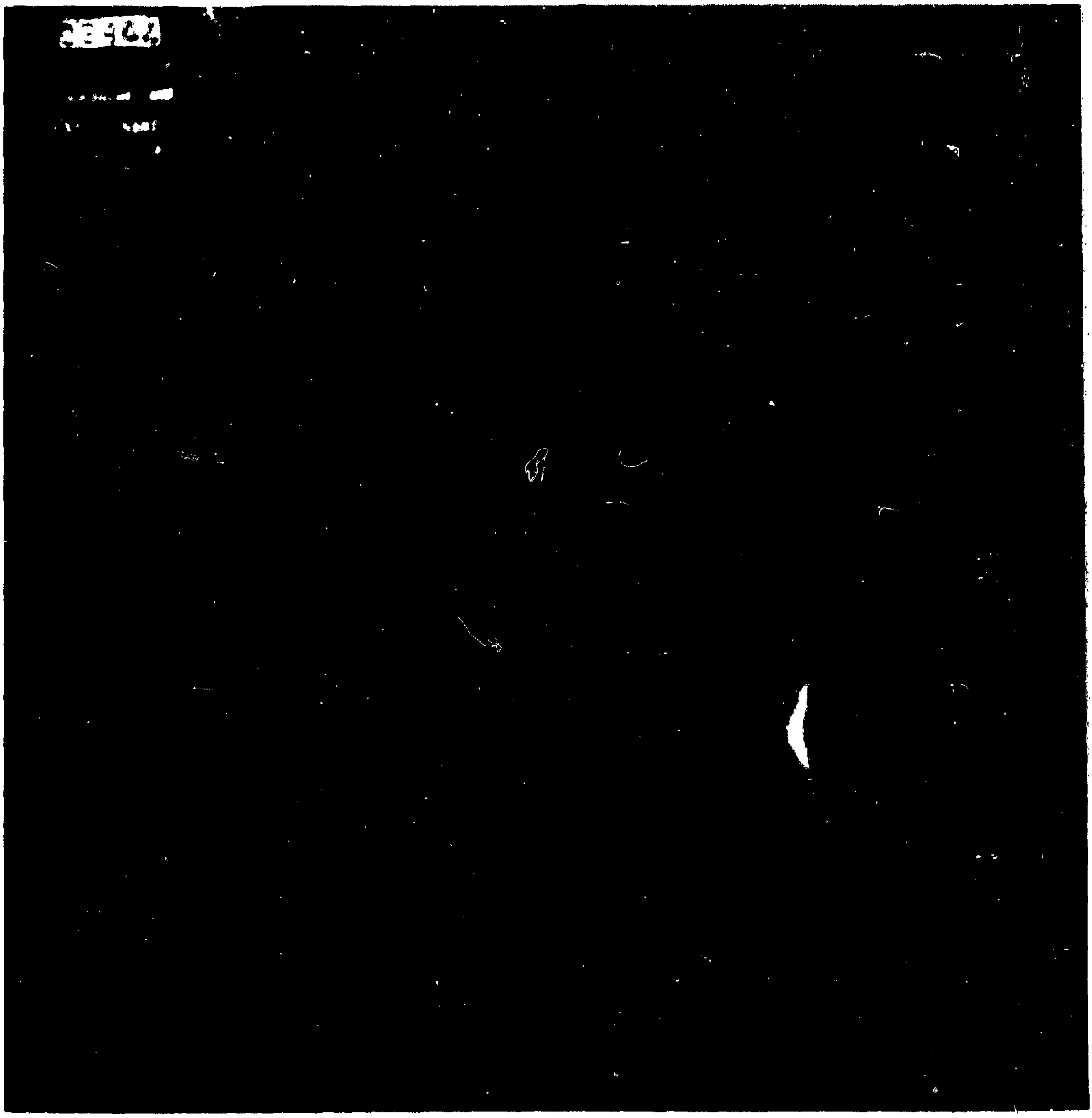


FIG. 31b - ROUND ELAGABULUS
TMA TRAIL
240.4 sec after launch
Station: St. Vincent North

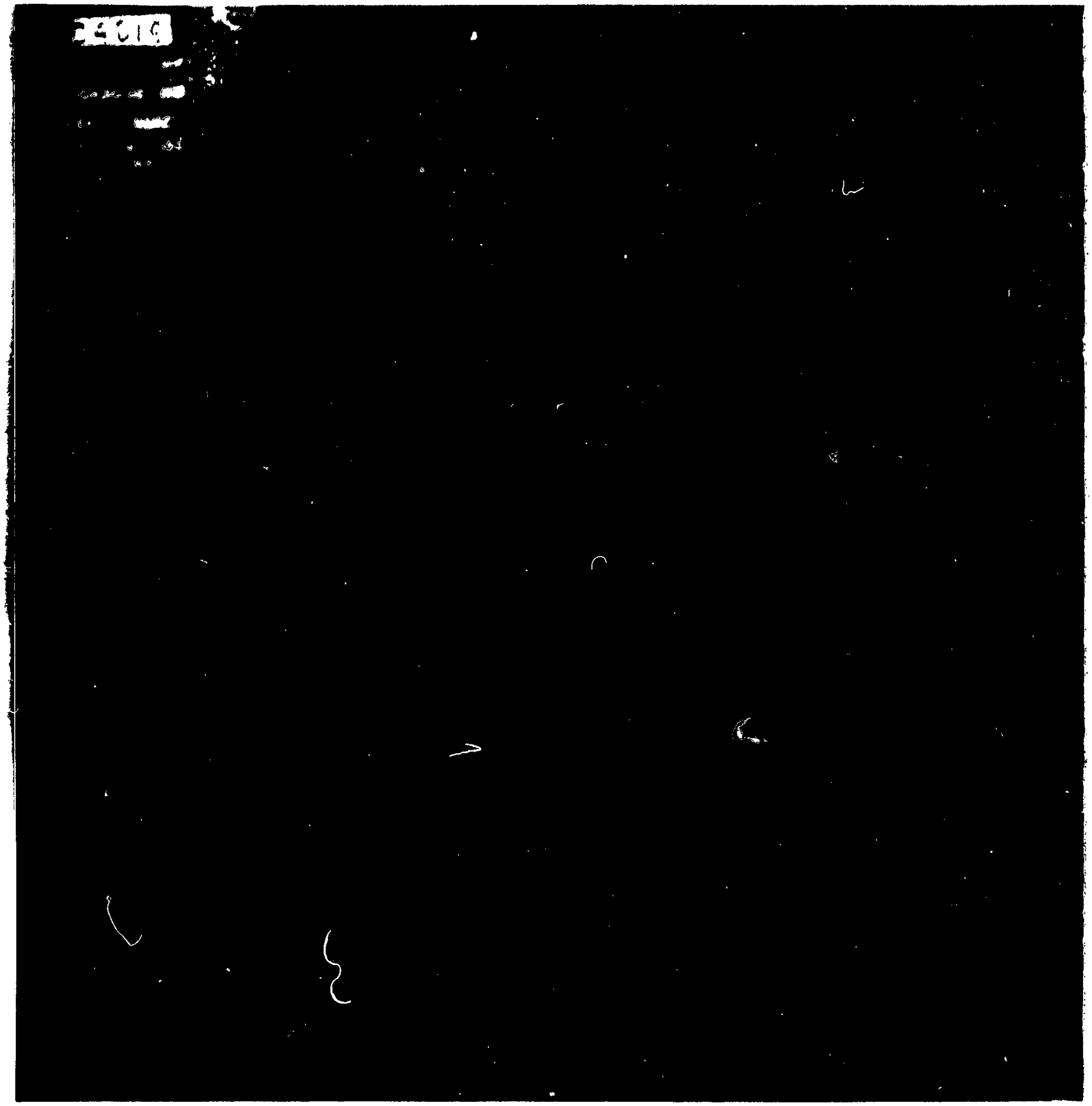


FIG. 31c - ROUND ELAGABULUS
TMA TRAIL
401.9 sec after launch
Station: St. Vincent North

TABLE VIII

SHOT MARIUS 3 JUNE 1965 19-57-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S)	
			N-S	E-W
102.0	279.5	59.3	9.7	-58.5
103.0	282.5	50.7	10.9	-49.5
104.0	306.7	37.2	22.2	-29.9
105.0	343.1	43.5	41.6	-12.7
106.0	318.0	21.6	16.1	-14.5
107.0	305.4	10.2	5.9	-8.3
108.0	229.8	10.2	-6.6	-7.8
109.0	219.4	12.5	-9.7	-8.0
110.0	211.6	14.0	-12.0	-7.3
111.0	219.8	17.1	-13.1	-11.0
112.0	245.3	29.9	-12.5	-27.2
113.0	256.6	25.6	-5.9	-24.9
114.0	258.4	12.7	-2.5	-12.4

TABLE IX

SHOT NERO 3 JUNE 1965 22-41-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S)	
			N-S	E-W
88.0	127.0	41.9	-25.2	33.5
89.0	122.5	45.8	-24.6	38.7
90.0	106.3	61.0	-17.1	58.5
91.0	108.1	68.2	-21.2	64.9
92.0	106.7	67.0	-19.2	64.2
93.0	105.7	62.6	-17.0	60.3
94.0	109.2	62.9	-20.7	59.4

TABLE [illegible]a

SHOT ELAGABULUS 4 JUNE 1965 01-34-56 AST
UP TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) N-S	E-W
91.0	201.4	30.2	-28.2	-11.0
92.0	195.6	23.6	-22.7	-6.3
93.0	185.9	15.8	-15.7	-1.6
94.0	259.0	4.8	-0.9	-4.7
95.0	25.8	19.0	17.1	8.3
96.0	21.0	26.7	25.0	9.6
97.0	25.0	47.9	43.4	20.3
98.0	26.1	42.9	38.5	18.9
99.0	30.1	52.4	45.4	26.3
100.0	27.5	50.0	44.3	23.1
101.0	281.3	14.5	2.9	-14.3
102.0	240.1	43.4	-21.6	-37.6
103.0	238.6	56.6	-29.5	-48.3
104.0	231.7	56.5	-35.0	-44.3
105.0	214.5	57.1	-47.1	-32.4
106.0	211.0	55.8	-47.8	-28.8
107.0	201.9	79.5	-73.8	-29.6
108.0	176.2	87.7	-87.5	5.8
109.0	189.1	101.2	-99.9	-16.0
110.0	194.1	105.4	-102.2	-25.7
111.0	197.8	100.9	-96.1	-30.8
113.0	226.5	96.8	-66.7	-70.2
114.0	238.4	105.5	-55.2	-89.9
115.0	249.7	94.8	-32.8	-89.0
116.0	256.9	87.8	-19.9	-85.5
117.0	279.7	70.7	11.9	-69.7
118.0	294.6	69.0	28.7	-62.7
119.0	302.8	71.6	38.8	-60.2
120.0	298.8	90.6	43.7	-79.4
121.0	291.3	77.8	28.2	-72.5

TABLE Xb

SHOT ELAGABULUS — 4 JUNE 1965 — 01-34-56 AST

DOWN TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) N-S	E-W
91.0	143.4	45.6	-36.7	27.2
92.0	182.0	43.7	-43.7	-1.6
93.0	141.6	53.2	-41.7	33.1
94.0	172.3	14.8	-14.6	2.0
95.0	22.4	27.0	25.0	10.3
96.0	17.1	36.7	35.0	10.8
97.0	19.1	46.1	43.6	15.1
98.0	17.1	50.9	48.6	15.0
99.0	20.3	49.4	46.3	17.1
100.0	21.6	41.6	38.7	15.3
101.0	1.7	9.5	9.5	0.3
102.0	238.0	40.6	-21.5	-34.4
103.0	235.5	52.4	-29.7	-43.2
104.0	218.6	62.1	-48.6	-38.7
105.0	205.3	58.5	-52.9	-25.0
106.0	180.7	109.3	-109.3	-1.4
107.0	176.2	117.9	-117.6	7.7
108.0	170.3	120.9	-119.2	20.3
109.0	178.1	126.5	-126.4	4.1
110.0	187.6	123.1	-122.0	-16.3
111.0	201.2	114.2	-106.4	-41.3
112.0	221.8	108.6	-80.9	-72.4
113.0	232.5	101.9	-62.0	-80.8
114.0	237.7	94.0	-50.2	-79.5
115.0	242.8	83.3	-38.0	-74.1
116.0	259.3	69.1	-12.9	-67.9
117.0	284.1	61.9	15.1	-60.1
118.0	290.8	57.9	20.6	-54.1
119.0	301.3	70.3	36.5	-60.1
120.0	315.9	49.6	35.6	-34.5
121.0	313.8	83.4	57.7	-60.2

TABLE XI

SHOT FABIUS		4 JUNE 1965	03-17-00 AST	
ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) N-S	E-W
92.0	179.0	59.8	-59.7	1.0
93.0	149.3	41.4	-35.6	21.2
96.0	21.1	48.3	45.1	17.4
97.0	21.8	49.4	45.9	18.3
98.0	21.6	48.9	45.5	18.0
99.0	21.0	40.0	37.3	14.3
101.0	146.9	49.6	-41.6	27.1
102.0	144.7	52.4	-42.8	30.2
103.0	141.2	55.2	-43.0	34.6
104.0	128.5	67.7	-42.2	53.0
105.0	132.1	63.8	-42.8	47.3
106.0	132.4	59.3	-40.0	43.8
107.0	193.1	47.2	-46.0	-10.7

TABLE XII

SHOT OVID		9 JUNE 1965	21-57-00 AST	
ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) N-S	E-W
95.0	238.3	39.7	-20.9	-33.8
96.0	243.9	39.0	-17.2	-35.1
97.0	243.9	39.2	-17.2	-35.3
98.0	296.4	33.2	14.7	-29.7
99.0	314.3	39.8	27.8	-28.5
100.0	230.9	30.4	-19.2	-23.6
101.0	206.6	36.5	-32.6	-16.4
102.0	176.4	46.5	-46.4	2.9
103.0	173.2	51.7	-51.3	6.1

TABLE XIII

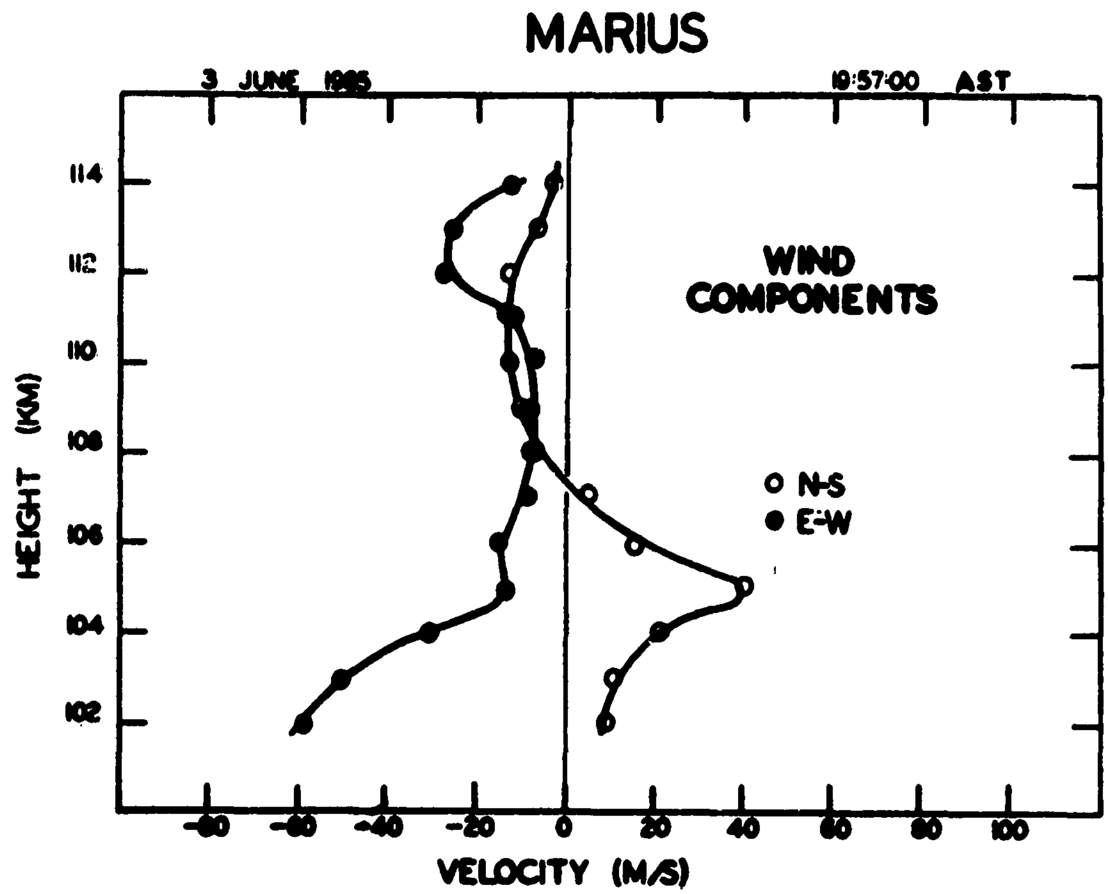
SHOT PLINY   10 JUNE 1965   21-07-00 AST

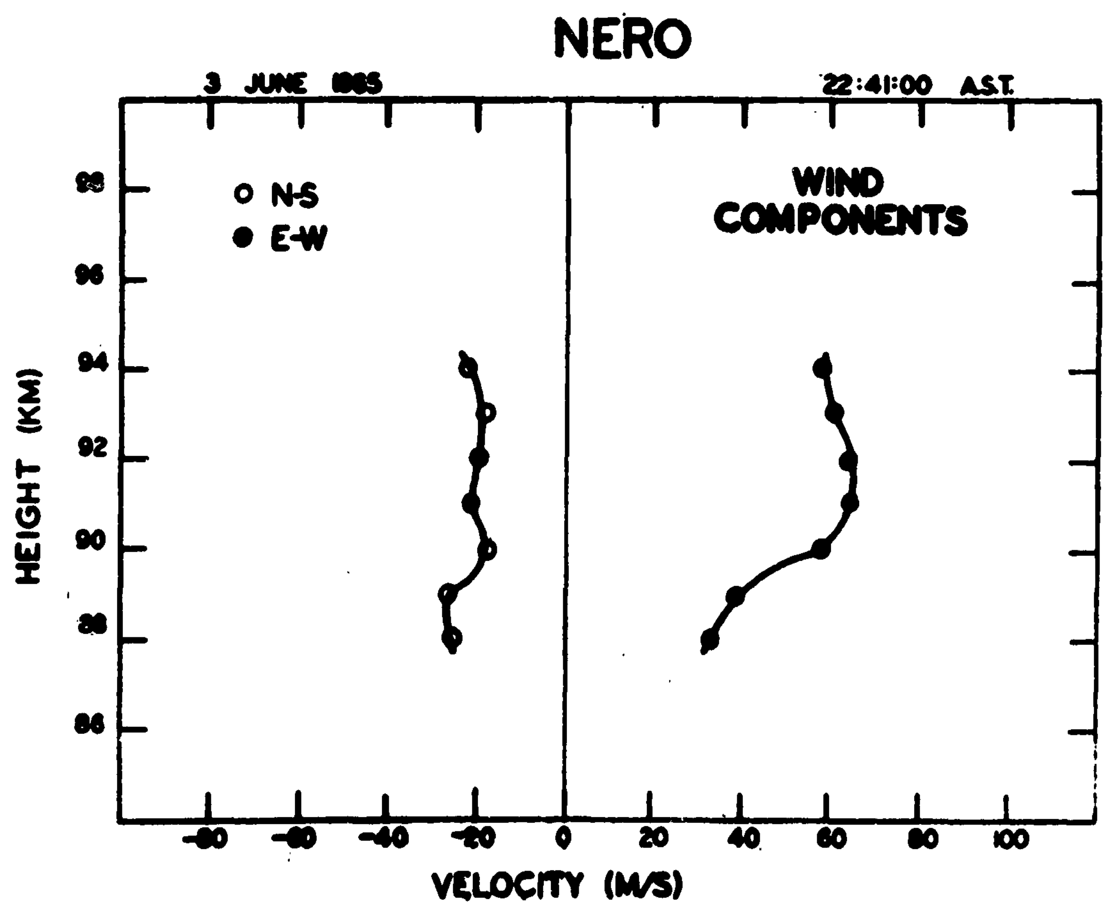
ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S)	
			N-S	E-W
97.0	112.1	58.8	-22.2	54.5
98.0	113.7	44.4	-17.8	40.5
99.0	116.0	35.7	-15.7	32.1
100.0	116.4	40.9	-18.2	36.6
101.0	114.2	50.4	-20.7	45.9
102.0	112.5	62.2	-23.7	57.4
103.0	110.8	67.3	-23.8	62.9
104.0	108.6	75.8	-24.1	71.8
105.0	105.9	75.2	-20.5	72.3
106.0	102.0	71.9	-15.0	70.4
107.0	93.1	52.3	-2.8	52.3
108.0	79.0	30.1	5.8	29.6

TABLE XIV

SHOT CICERO   9 JUNE 1965   23-57-50 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S)	
			N-S	E-W
91.0	212.0	56.0	-47.5	-29.6
92.0	220.0	42.6	-32.7	-27.4
93.0	229.6	57.4	-37.2	-43.7
94.0	236.8	81.4	-44.6	-68.1
95.0	243.8	76.5	-33.8	-68.6
96.0	237.3	52.0	-28.1	-43.8
97.0	277.8	35.8	4.8	-35.5
98.0	254.6	31.9	-8.5	-30.8
99.0	197.1	26.0	-24.9	-7.7
100.0	151.9	32.7	-28.8	15.4
101.0	152.2	48.0	-42.4	22.4
102.0	165.3	67.2	-65.0	17.0
103.0	170.0	86.7	-85.4	15.0





Figs. 32a and 33a

MARIUS

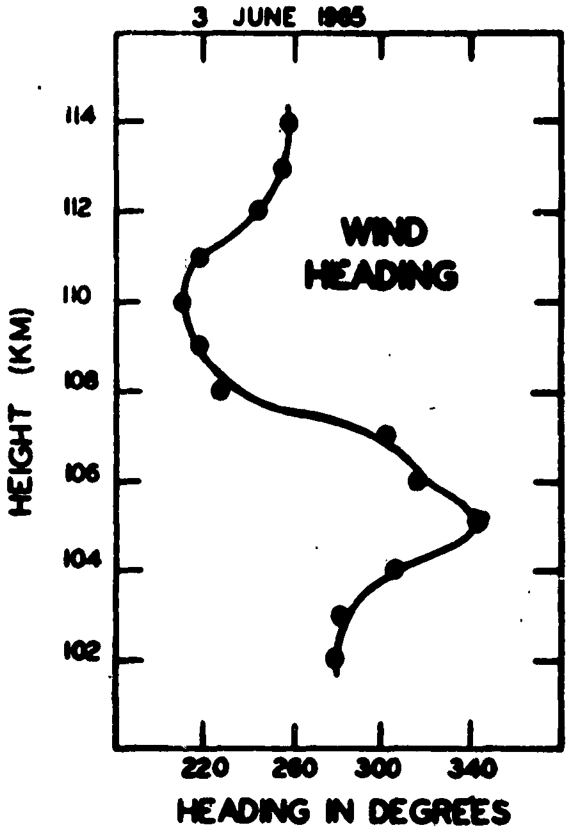


Fig. 32b

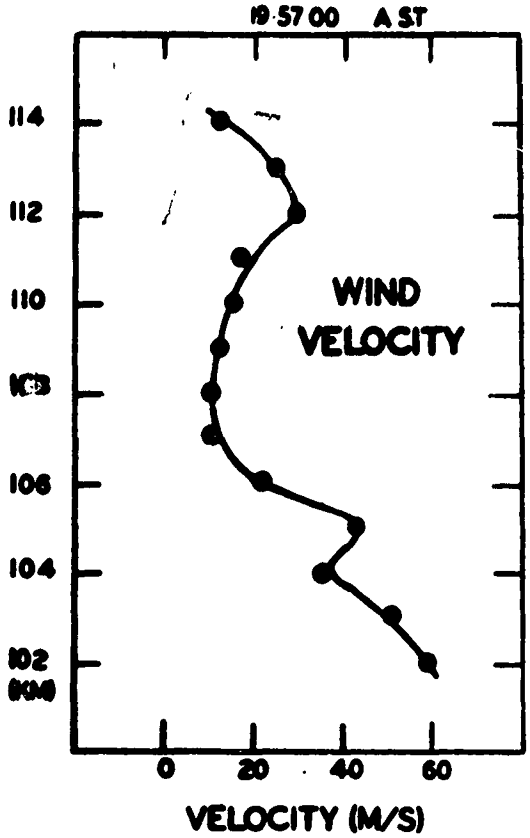


Fig. 32c

NERO

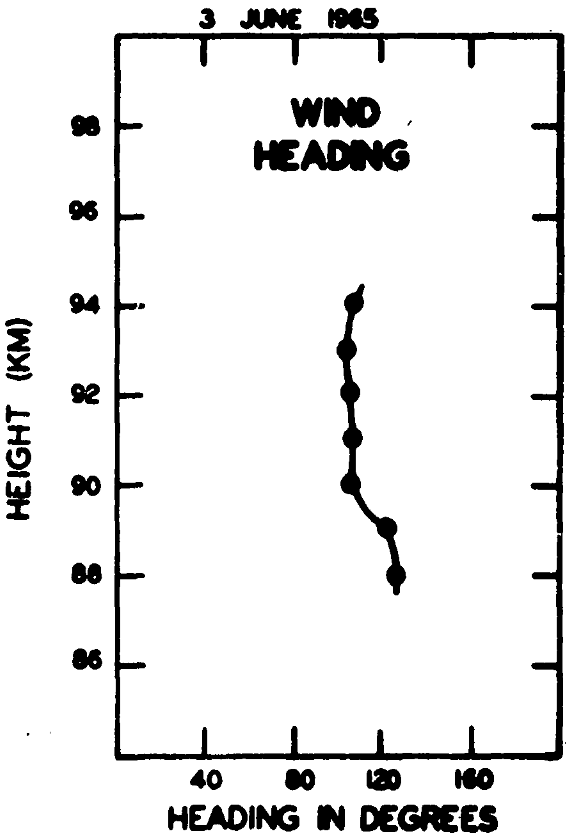


Fig. 33b

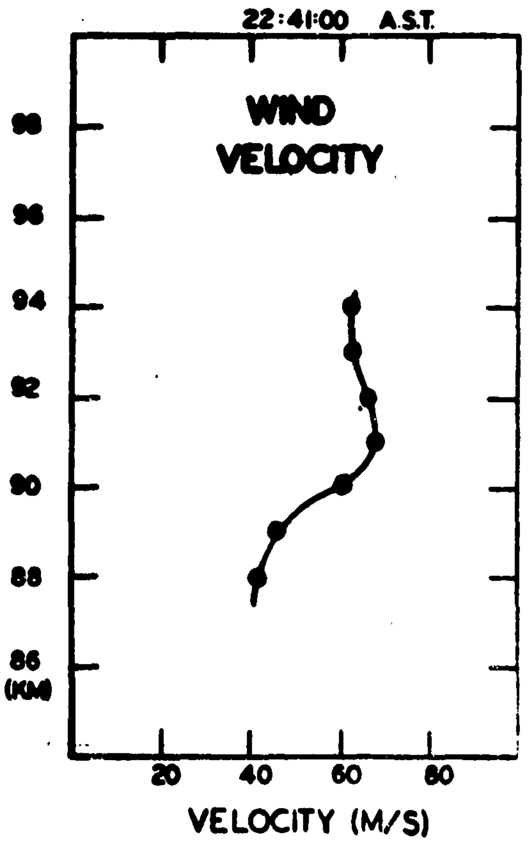
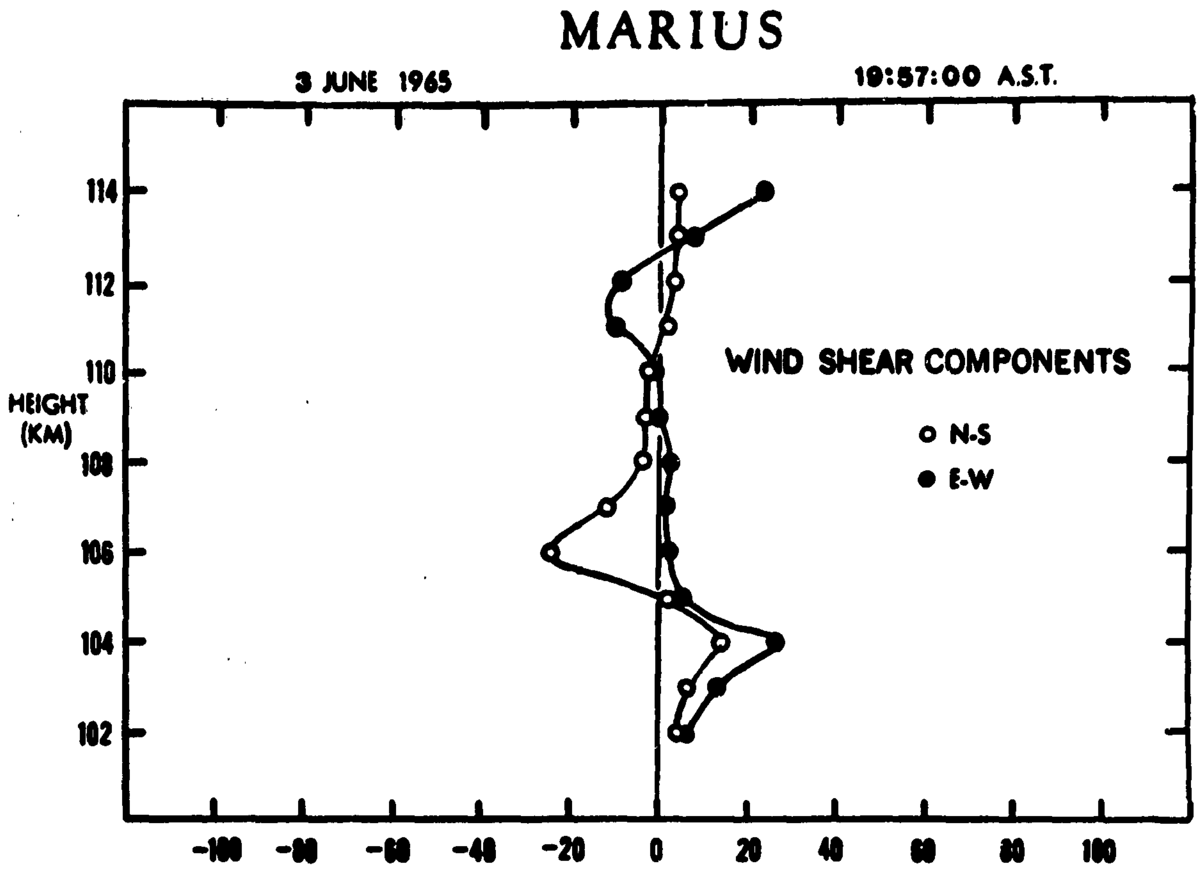
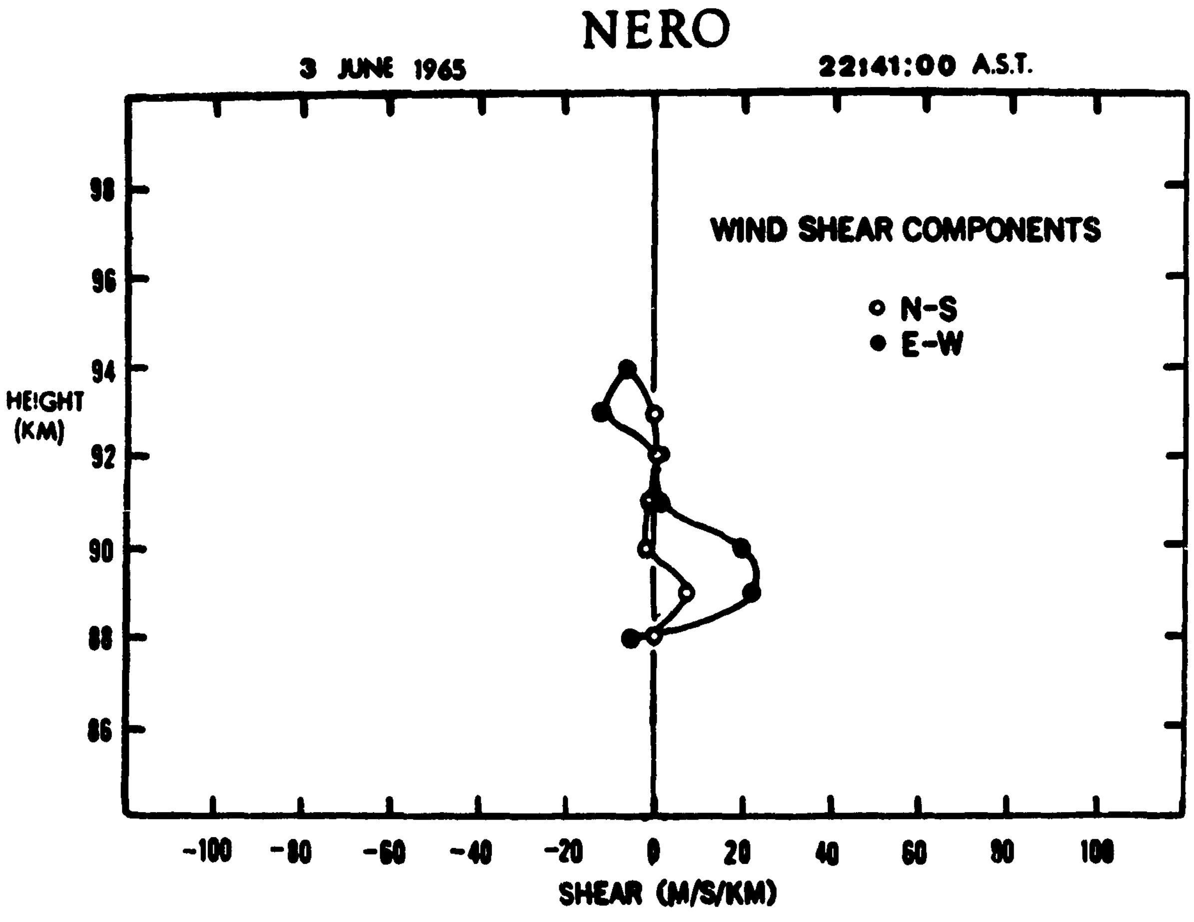


Fig. 33c





Figs. 32d and 33d

ELAGABULUS

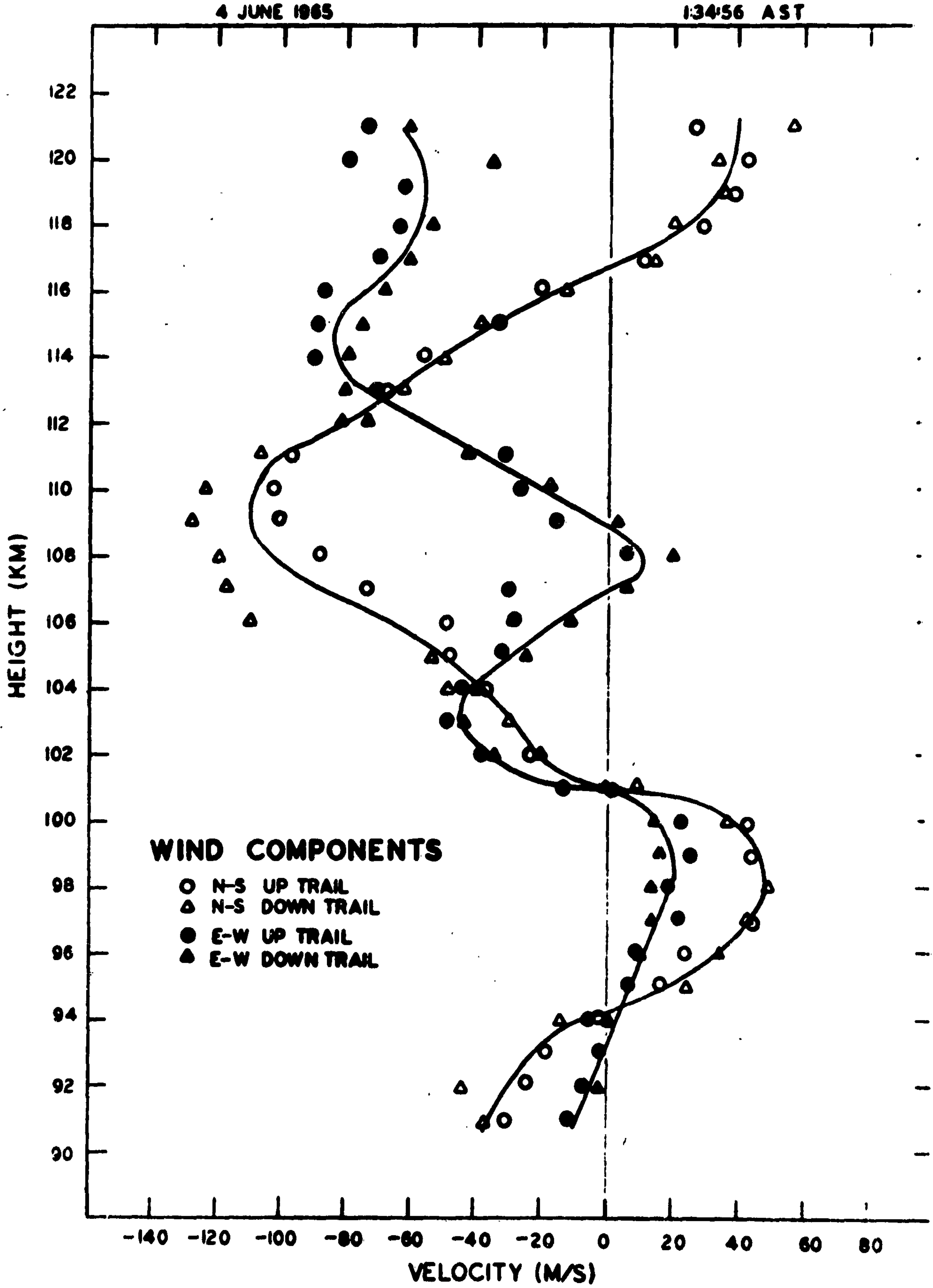


Fig. 34a

ELAGABULUS

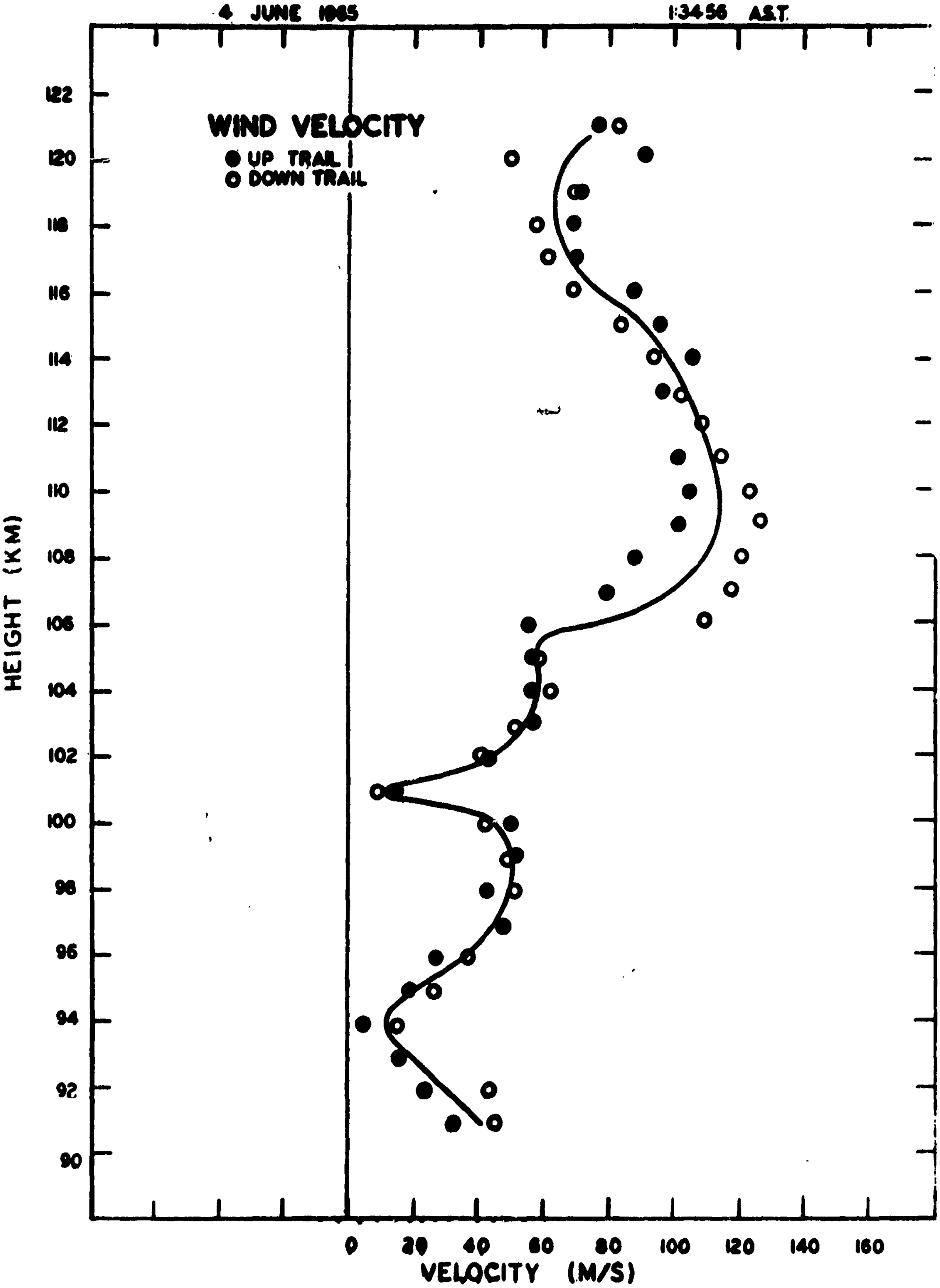


Fig. 34b

ELAGABULUS

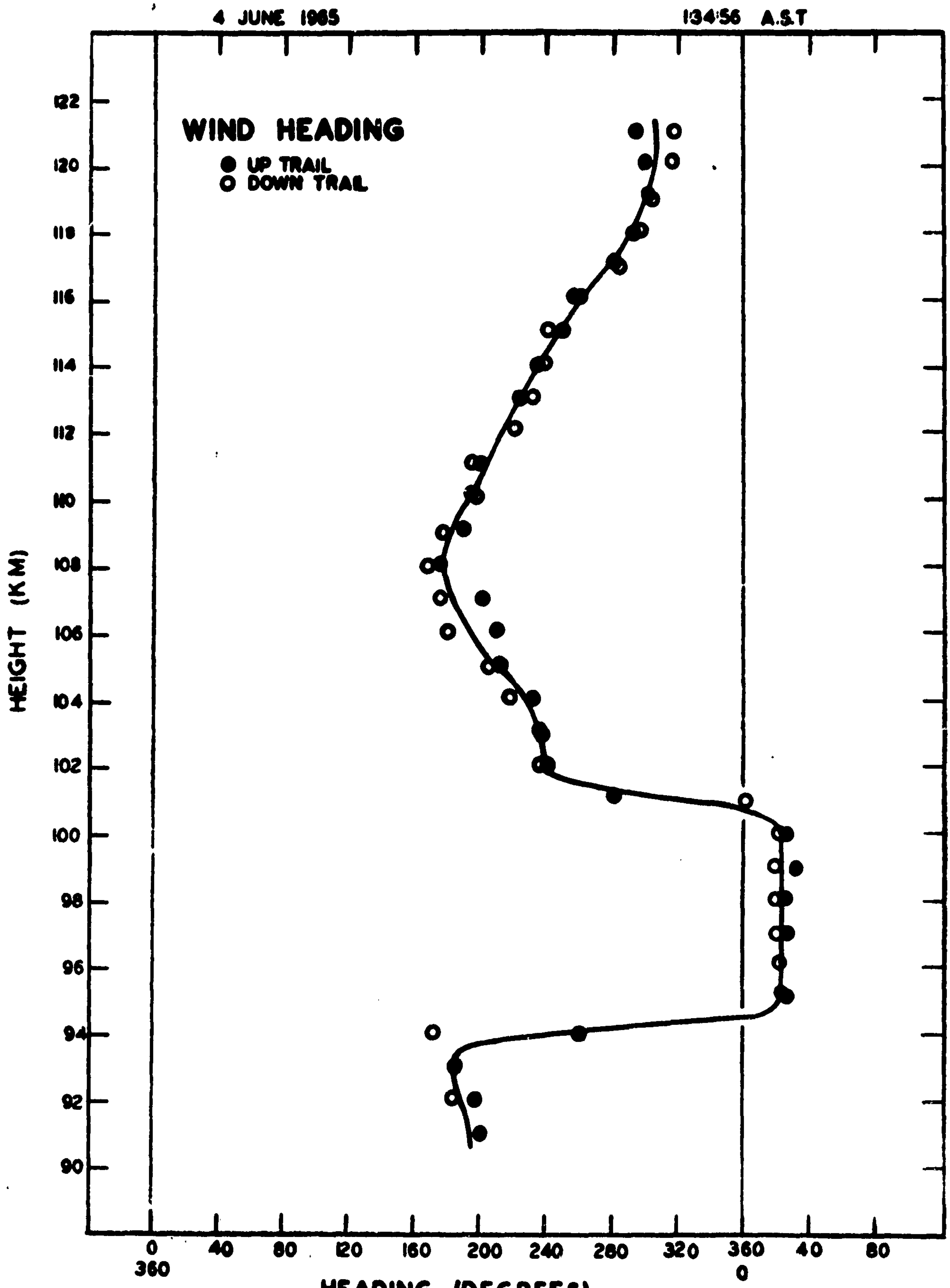


Fig. 34c

ELAGABULUS

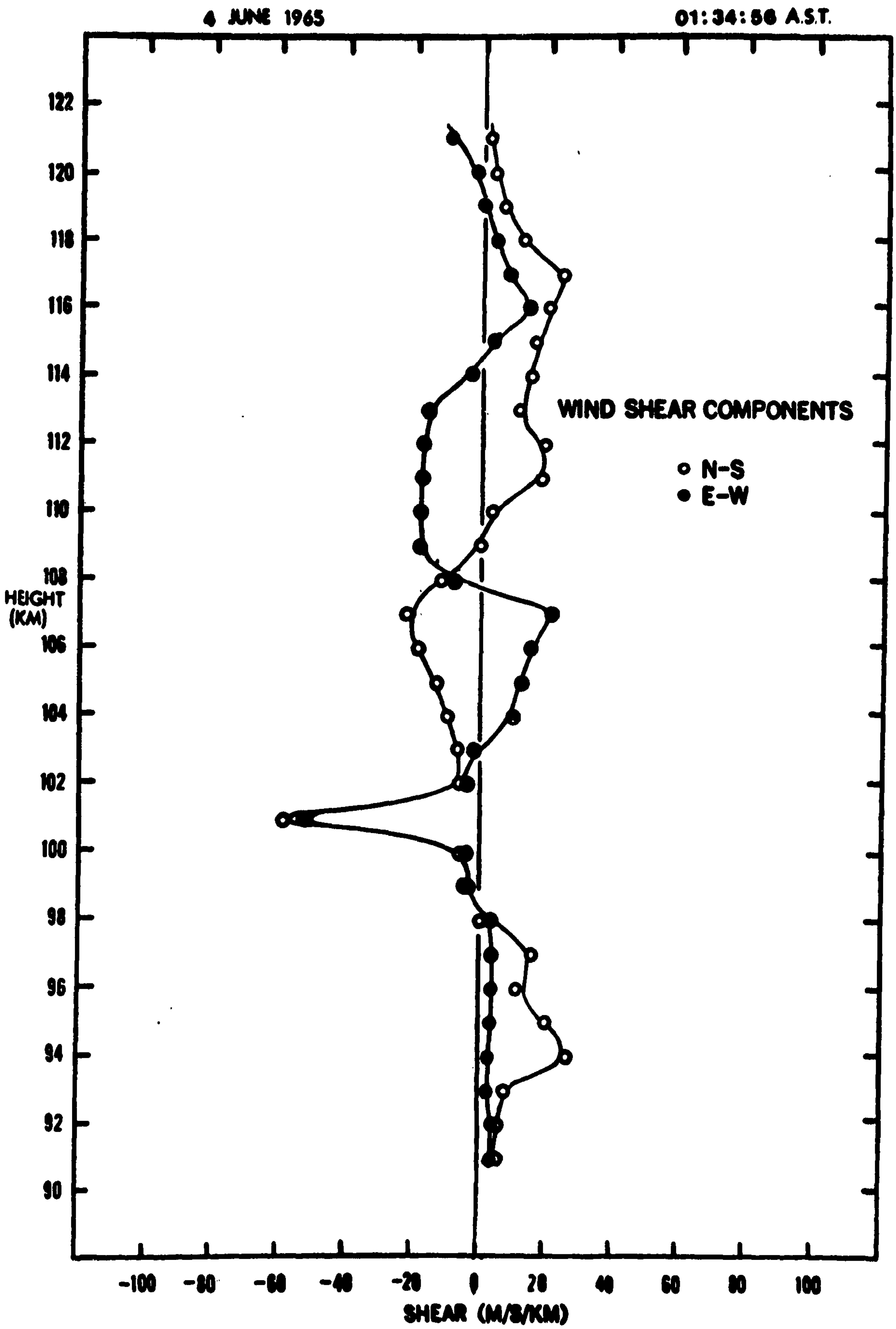


Fig. 34d

FABIUS

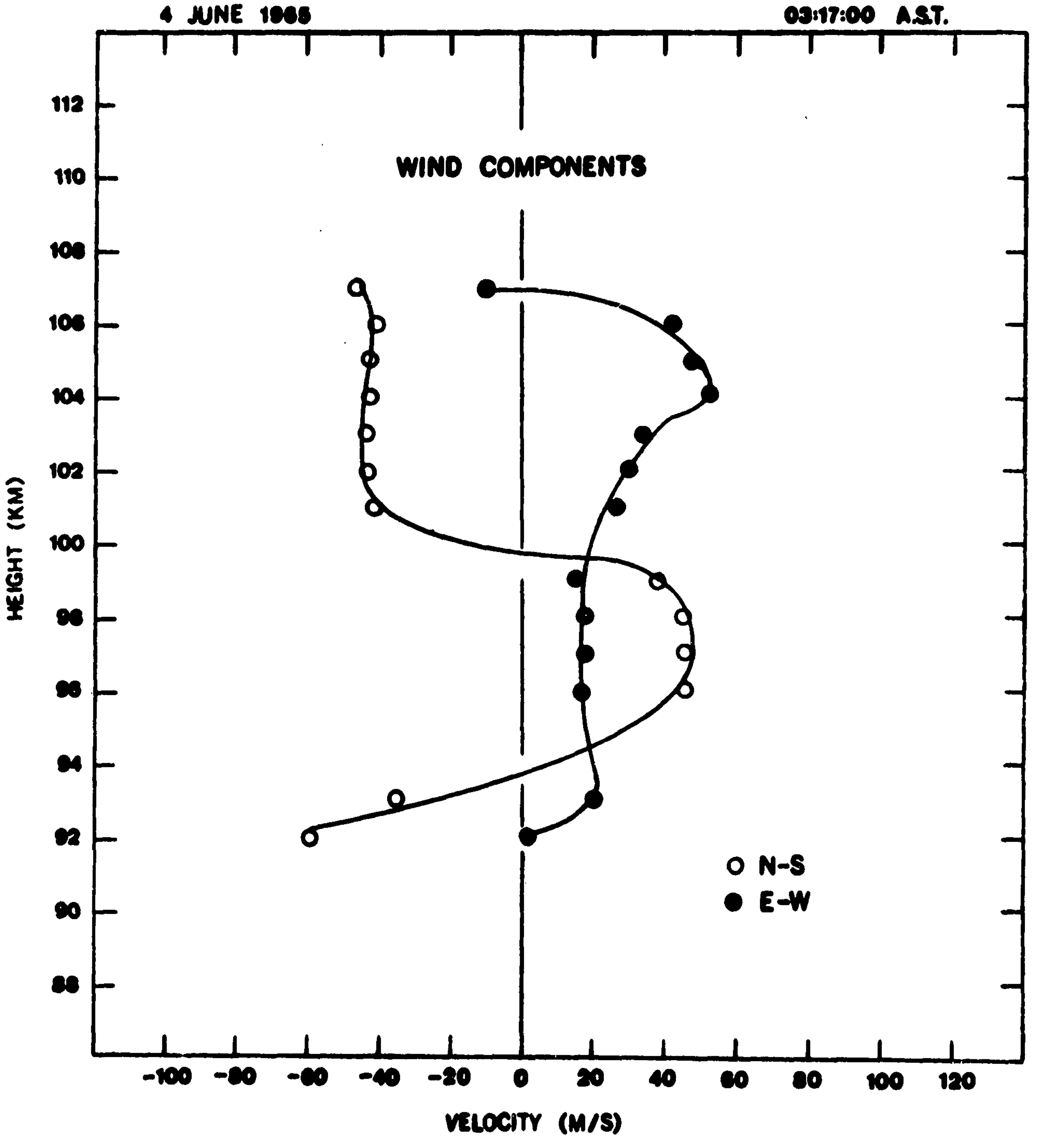


Fig. 35a

FABIUS

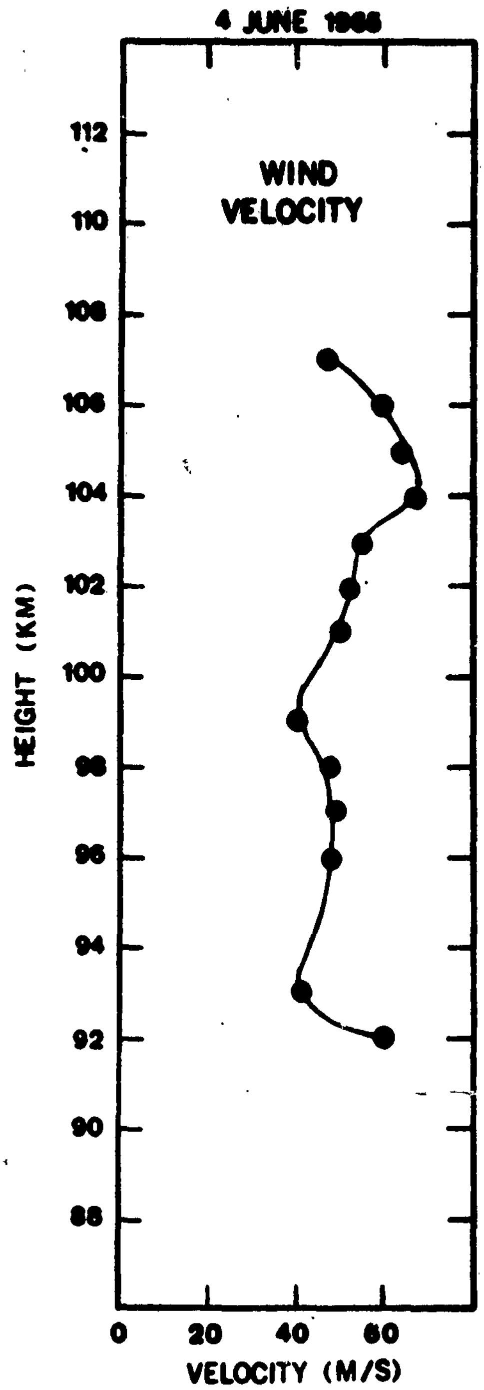


Fig. 35b

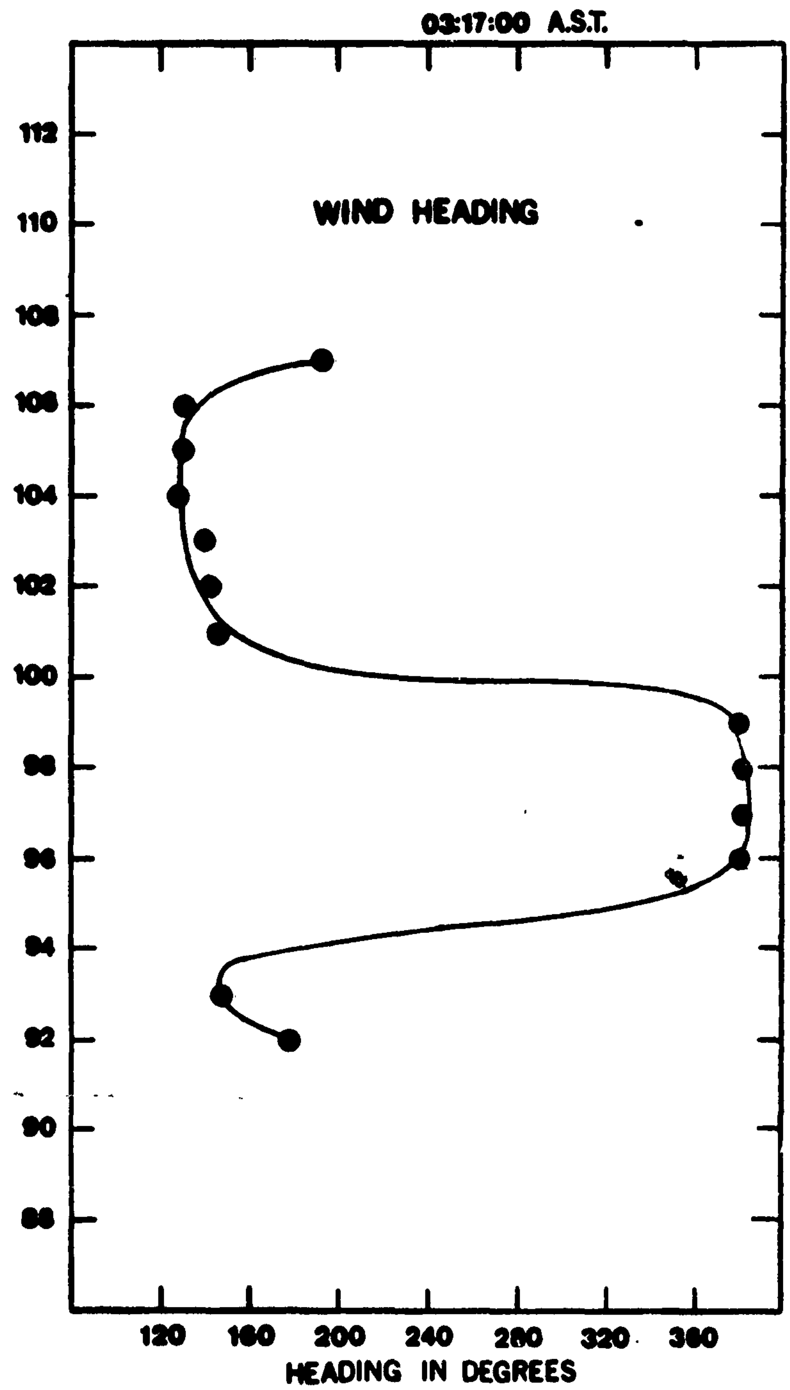


Fig. 35c

FABIUS

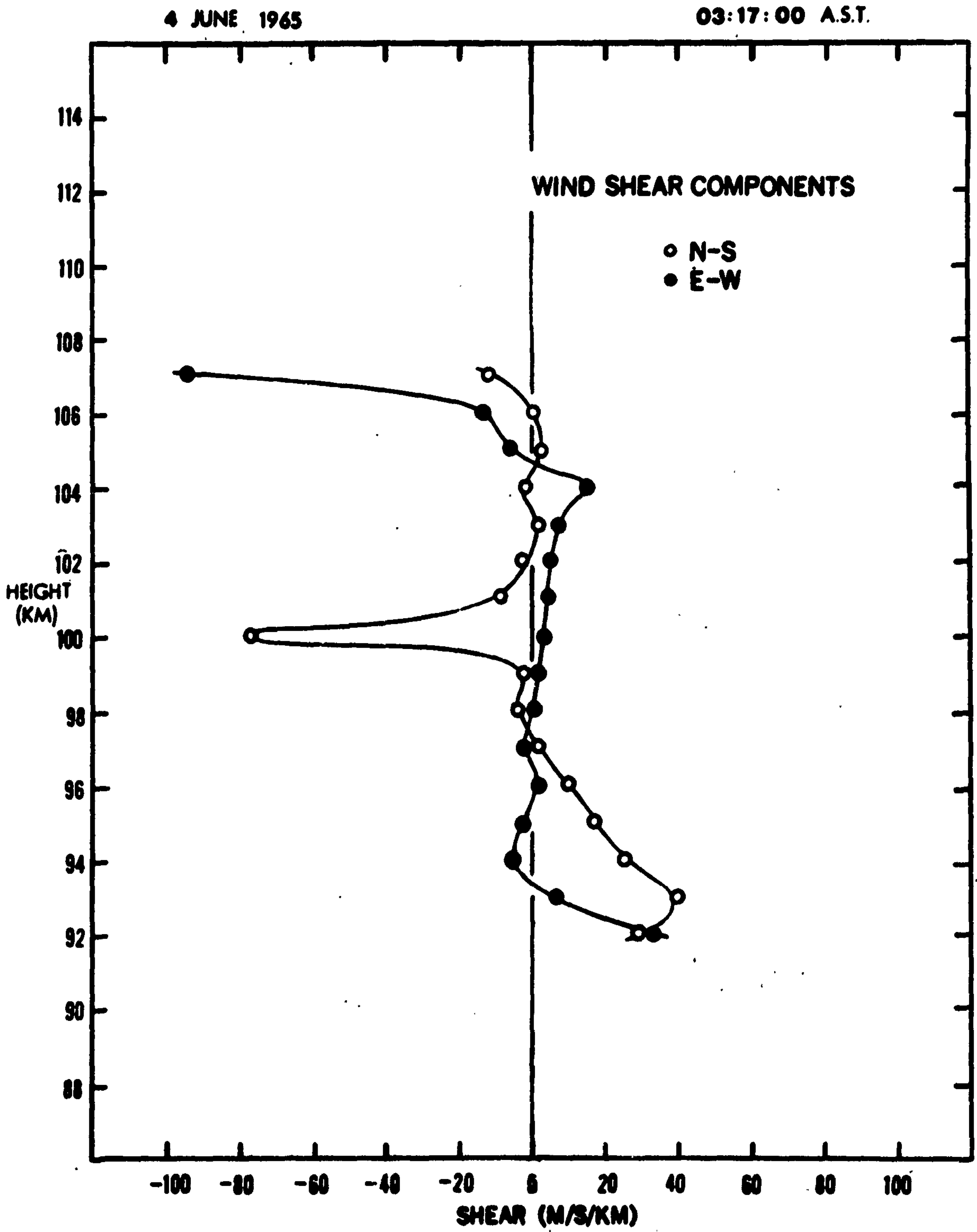
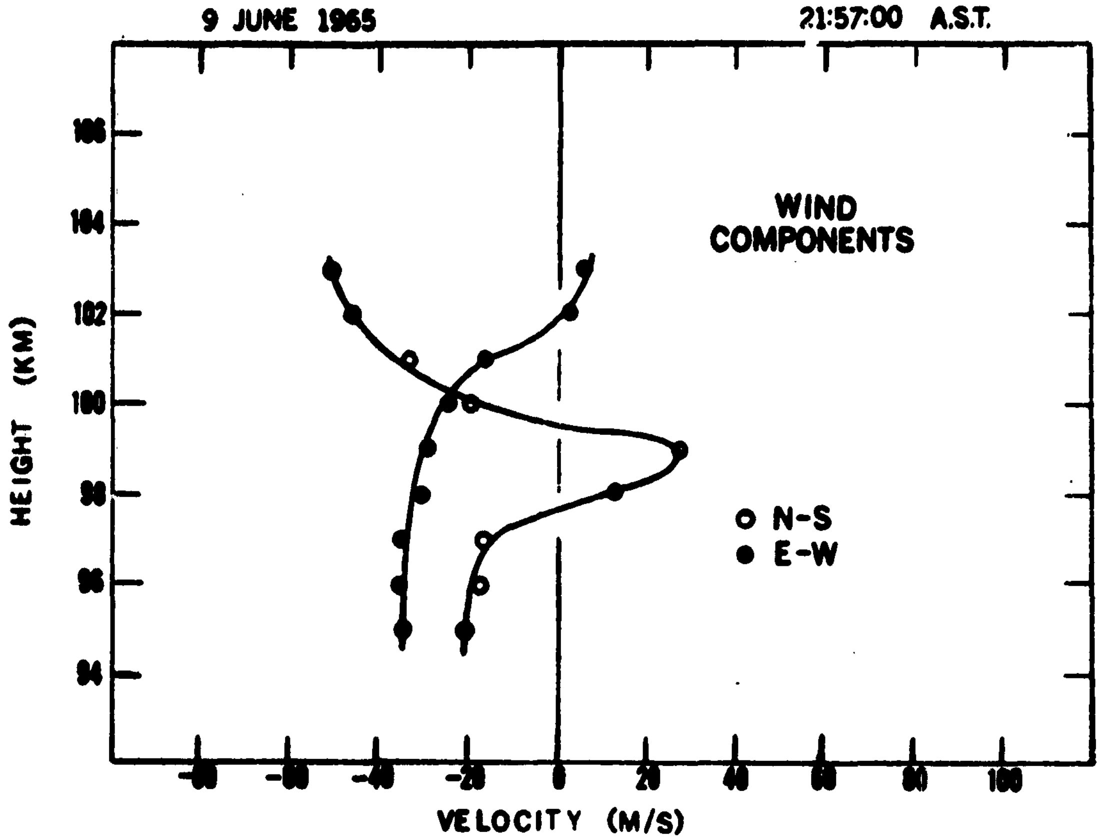
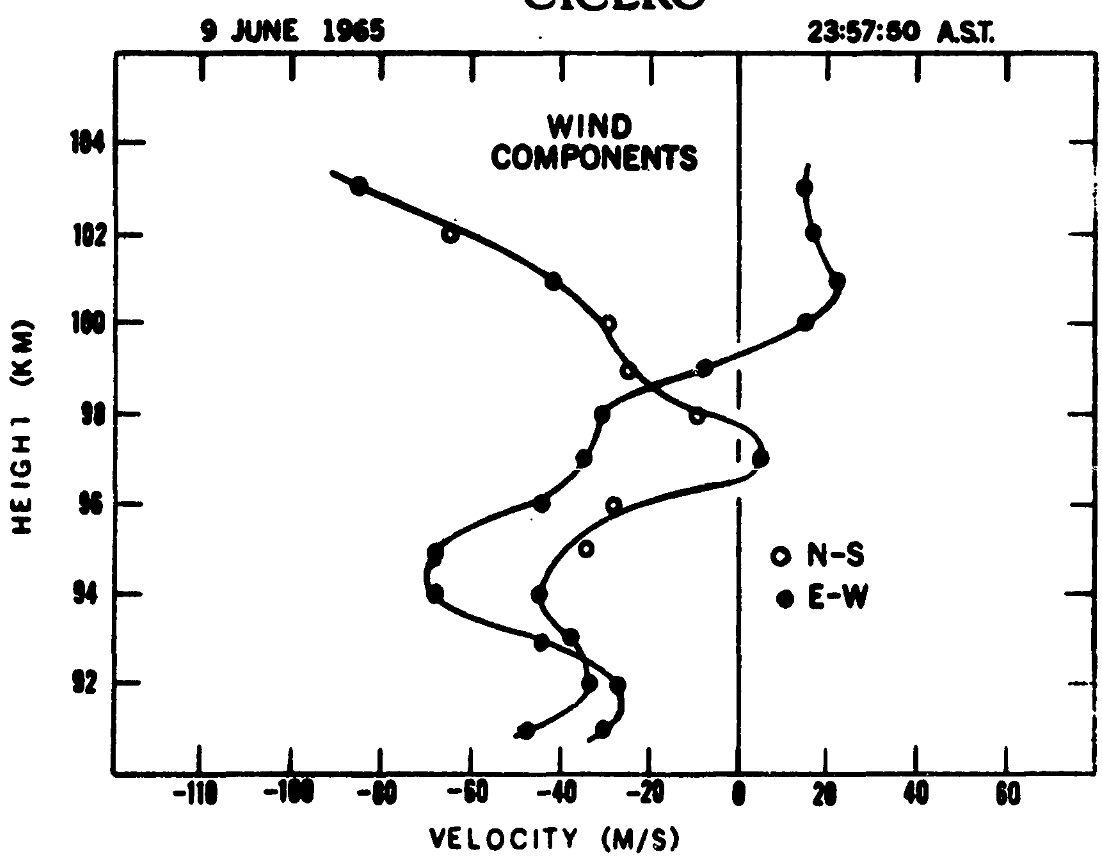


Fig. 35d

OVID



CICERO



Figs. 36a and 37a

OVID

9 JUNE 1965

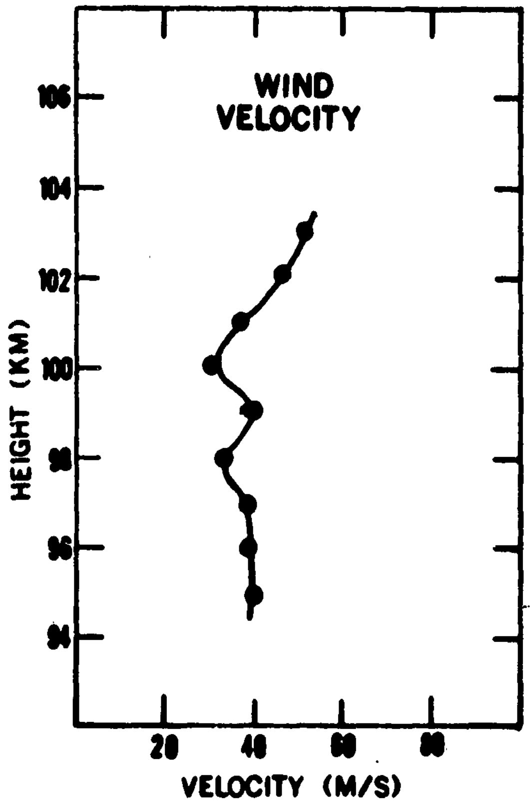


Fig. 36b

21:57:00 A.S.T.

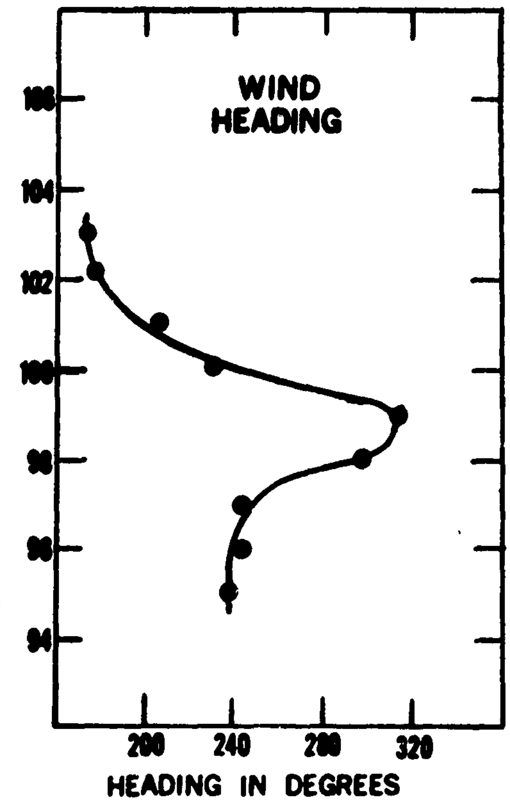


Fig. 36c

CICERO

9 JUNE 1965

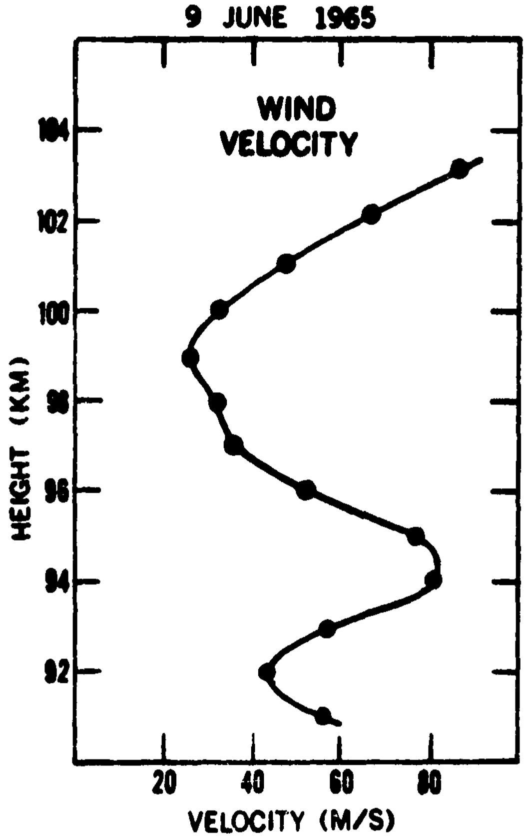


Fig. 37b

23:57:50 A.S.T.

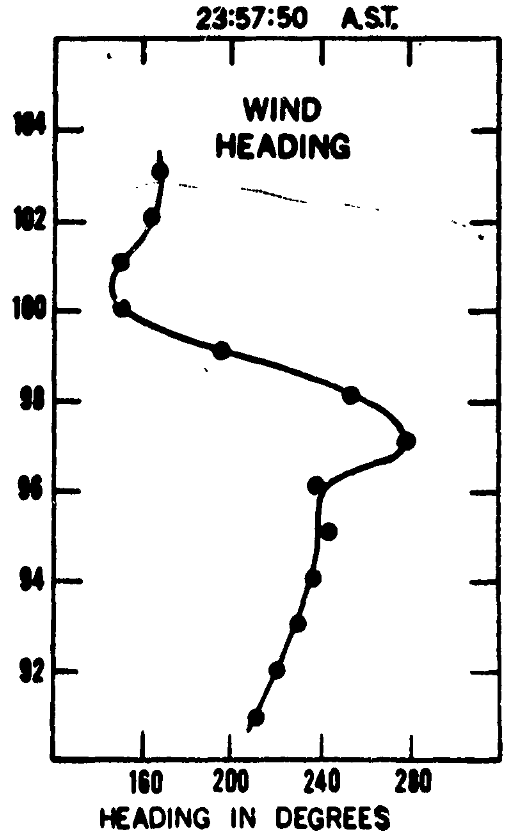
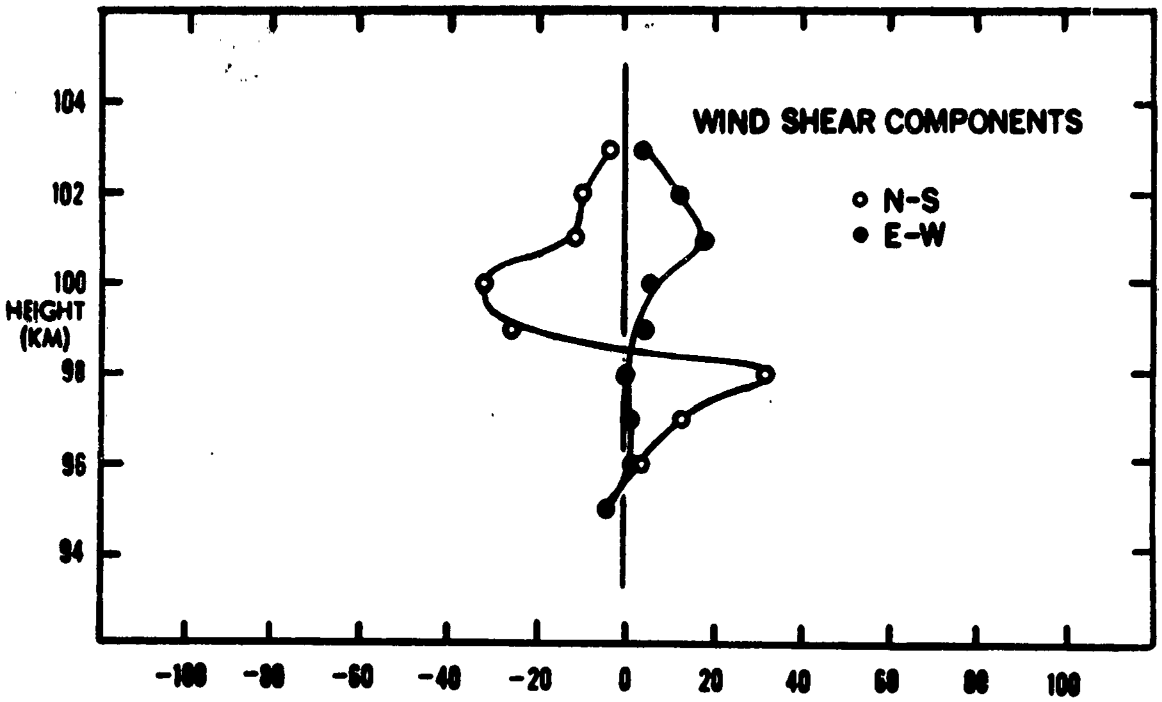


Fig. 37c

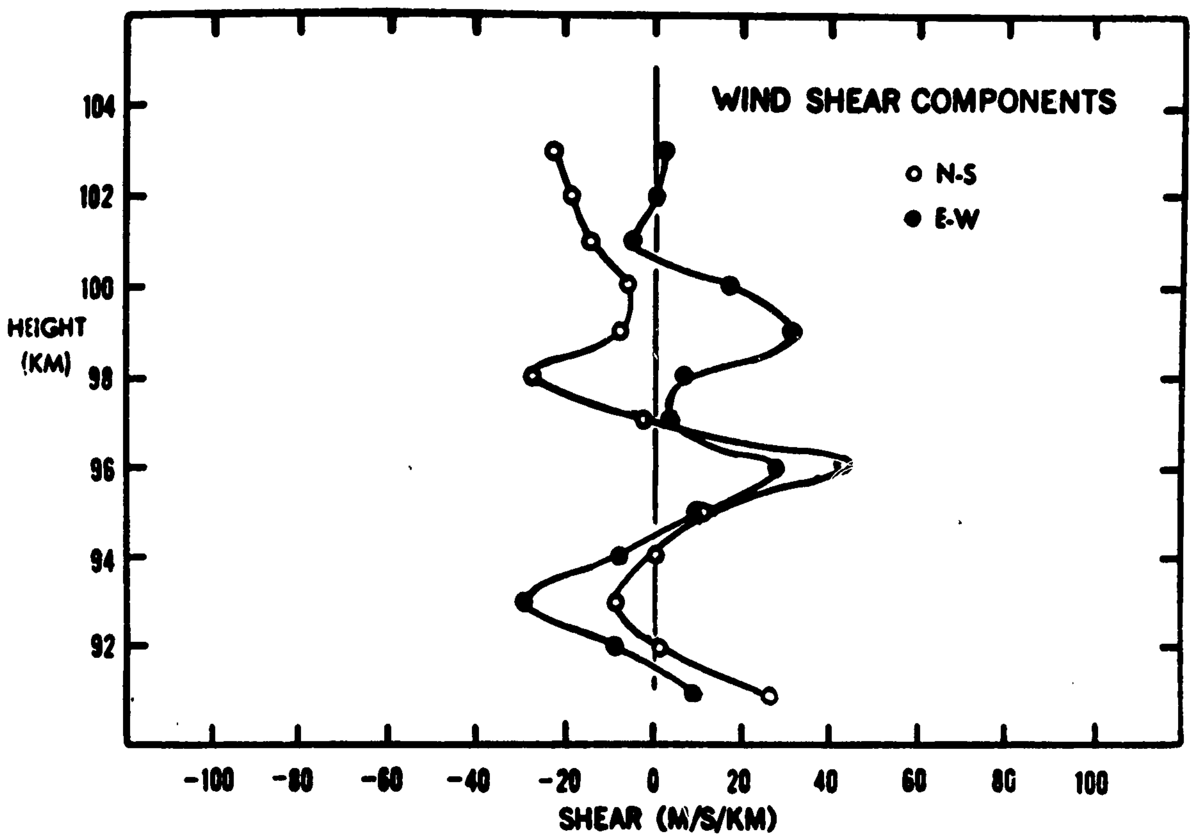
OVID

9 JUNE 1965 21:57:00 A.S.T.



CICERO

9 JUNE 1965 23:57:50 A.S.T.



Figs. 36d and 37d

PLINY

10 JUNE 1965 21.07.00 A.S.T.

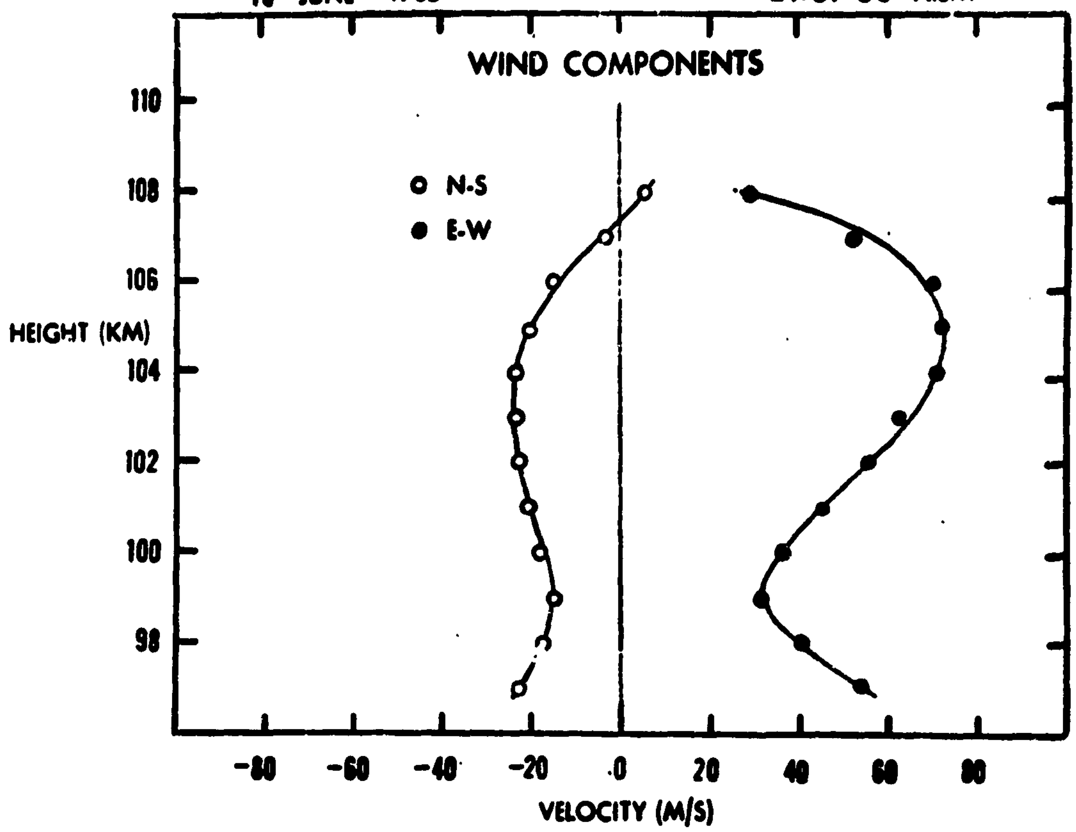


Fig. 38a

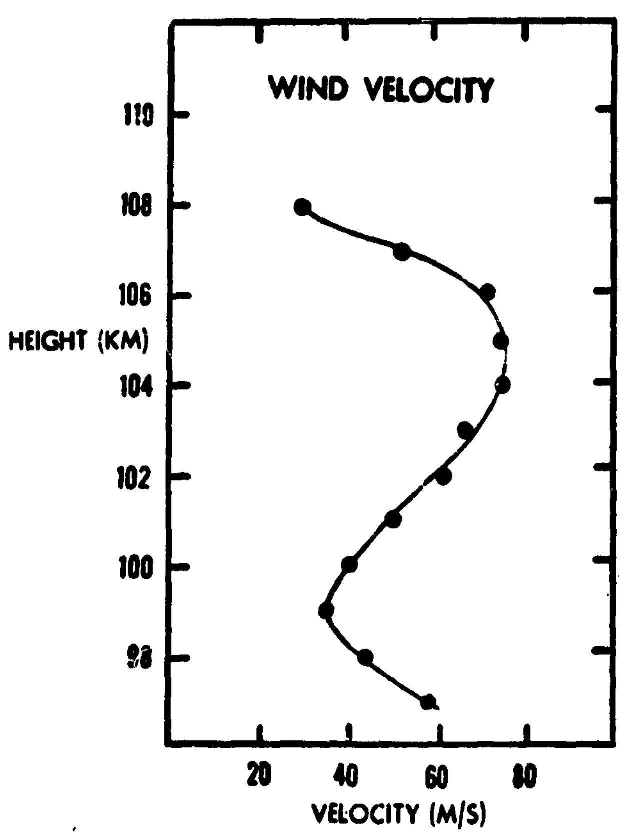


Fig. 38b

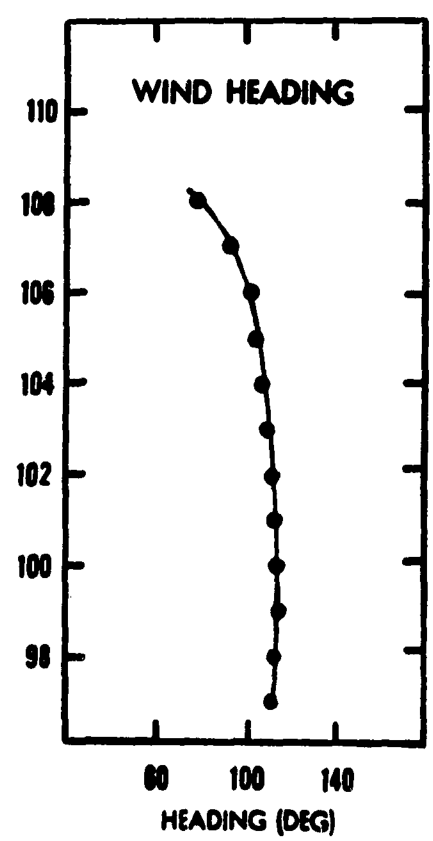


Fig. 38c

PLINY

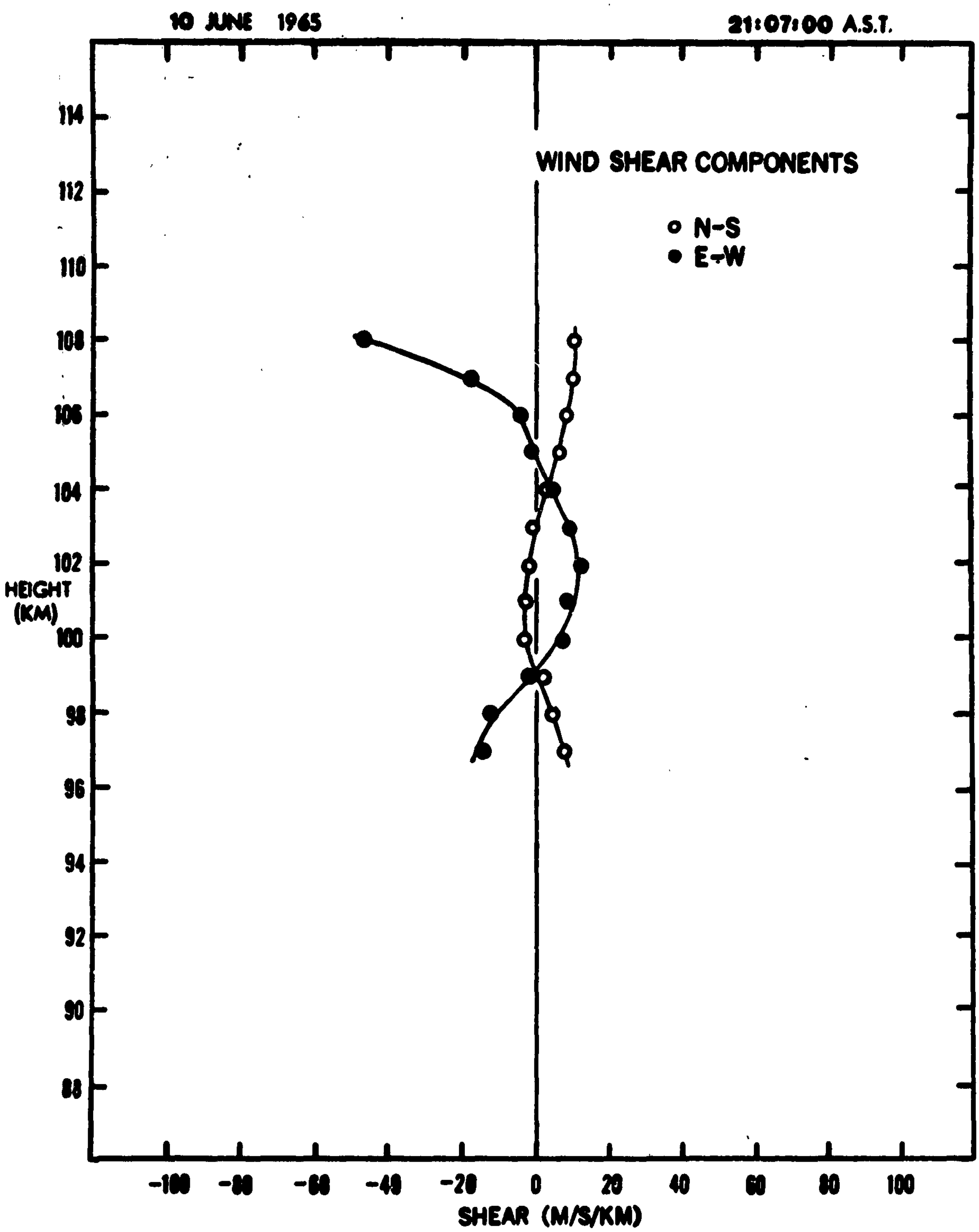


Fig. 38d

9.0 RESULTS OF SPECIAL EXPERIMENTS (Reported by BRL)

9.1 250 MHz Telemetry Experiments

Rounds LUCRETIA, CICERO and DIANA (Nos. 14, 16, and 17) were instrumented with Schoenstedt magnetometers and thermistor temperature gauges. The purpose of the tests was to demonstrate the feasibility of using flux-gate magnetometers on HARP vehicles. Since the flux-gate magnetometers are temperature sensitive, a thermistor was located in the vicinity of each magnetometer to record the in-flight temperatures experienced. The location of magnetometer and thermistor in the 2C vehicle is shown in Fig. 39.

The telemeter consisted of a 250 MHz FM transmitter coupled to a nose-spike antenna and modulated by two subcarrier oscillators, one for the magnetometer and one for the thermistor, operating at nominal values of 40 KHz and 10.5 KHz respectively. The antenna pattern for this antenna-transmitter configuration is shown in Fig. 40. The pattern shows a null at the rear of the vehicle.

Fig. 41 shows the arrangement of instruments in the ground station. The flight data were recorded on magnetic tape and for some of the data on an oscillograph recorder. The receiving antennas were eight-turn helices with nominal gain of 10 db.

In the following sections, the results from LUCRETIA, CICERO, and DIANA are described in detail.

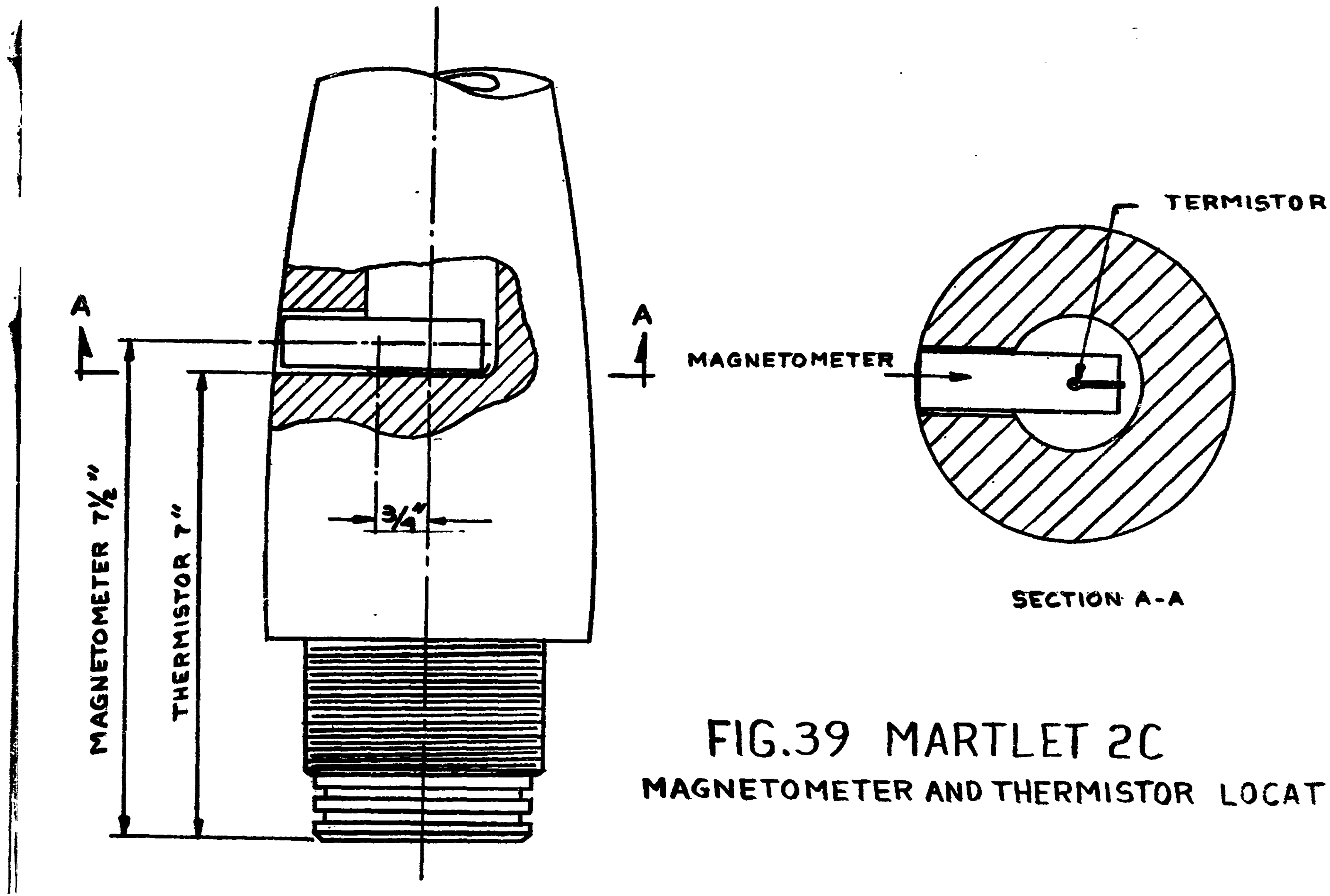


FIG.39 MARTLET 2C
MAGNETOMETER AND THERMISTOR LOCATION

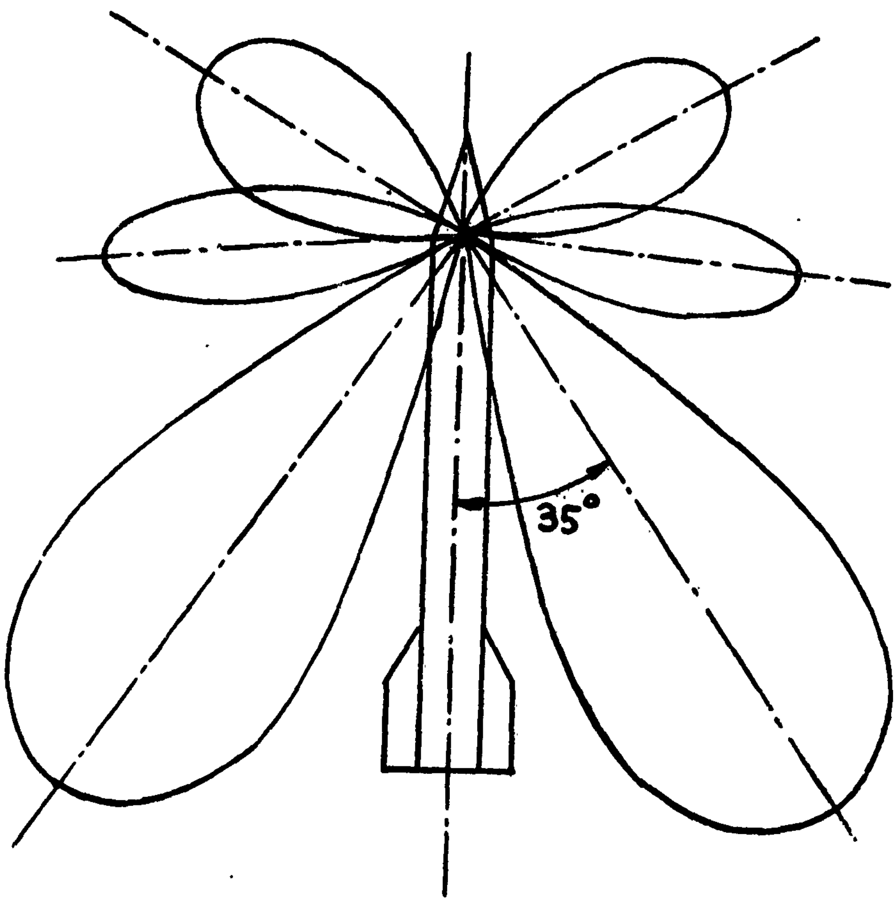


FIG.40 MARTLET 2C ANTENNA PATTERN

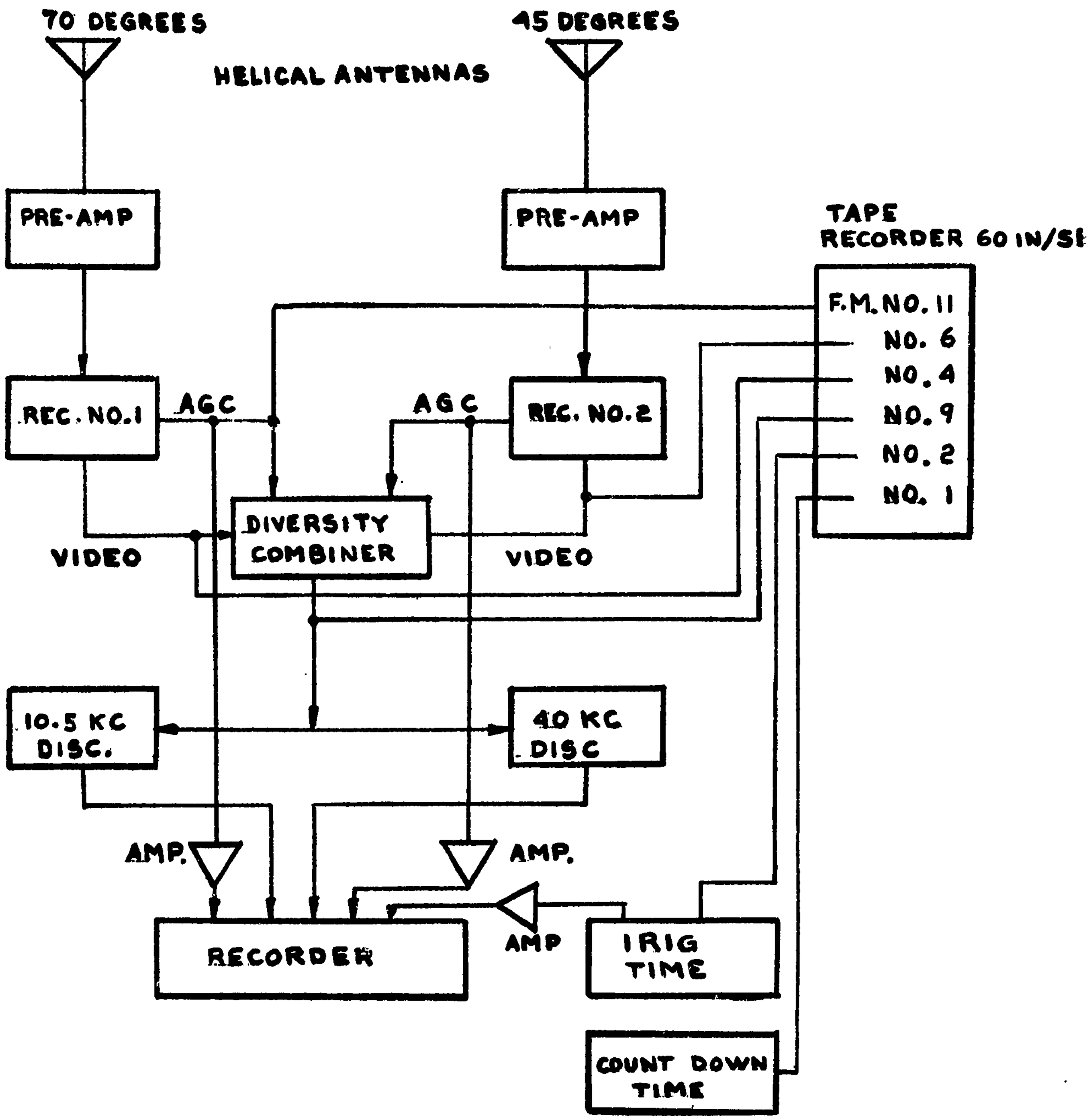


FIG. 41 BLOCK DIAGRAM FOR GROUND STATION TELEMETRY (PARAGON)

9.1.1 Round No. 14 - LUCRETIA

Telemetry signals were received from round LUCRETIA for the first ten seconds of flight, after which the signals were lost until about T + 210 sec. Data were received from T + 210 to T + 295 sec. The received signals indicated that both subcarriers were functioning but had been shifted considerably off centre frequency. The magnetometer channel subcarrier had shifted about 6 KHz (12 percent) and the temperature channel subcarrier had shifted about 800 Hz (8 percent). A shift in transmitter frequency of 2 MHz was also observed after launch.

The data from the magnetometer channel show that the Schoenstedt device survived the gun launch and was able to perform during flight. Although the severe subcarrier centre frequency shift may have resulted in a change of input sensitivity, the data have been treated as though the ground calibrations were valid. Fig. 42 shows envelope of the peak magnetic field intensity observed during the latter portion of the flight as a function of flight time. Fig. 43 shows the roll rate for the 2C vehicle as derived from the magnetometer data.

The temperature data channel indicated that the bead thermistor functioned during the flight. Fig. 44 shows the reduced temperature data, corrected for subcarrier centre frequency shift. A maximum temperature of about 150 deg F was observed at the interior of the 2C vehicle.

The ground calibration data for LUCRETIA are shown in Table XV.

ROUND LUCRETIA (MARTLET 2C)

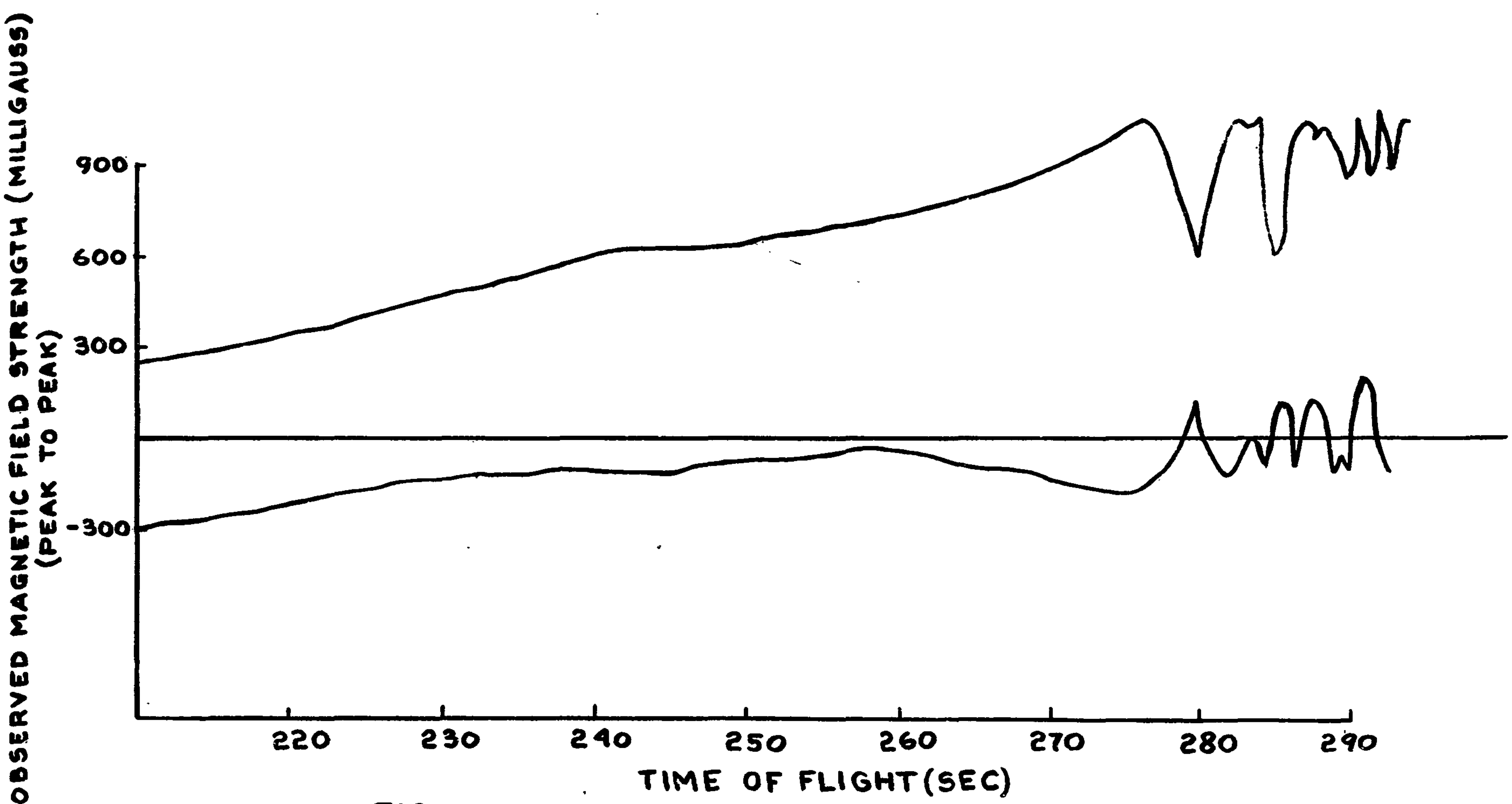


FIG.42 MAGNETIC FIELD STRENGTH VS FLIGHT TIME

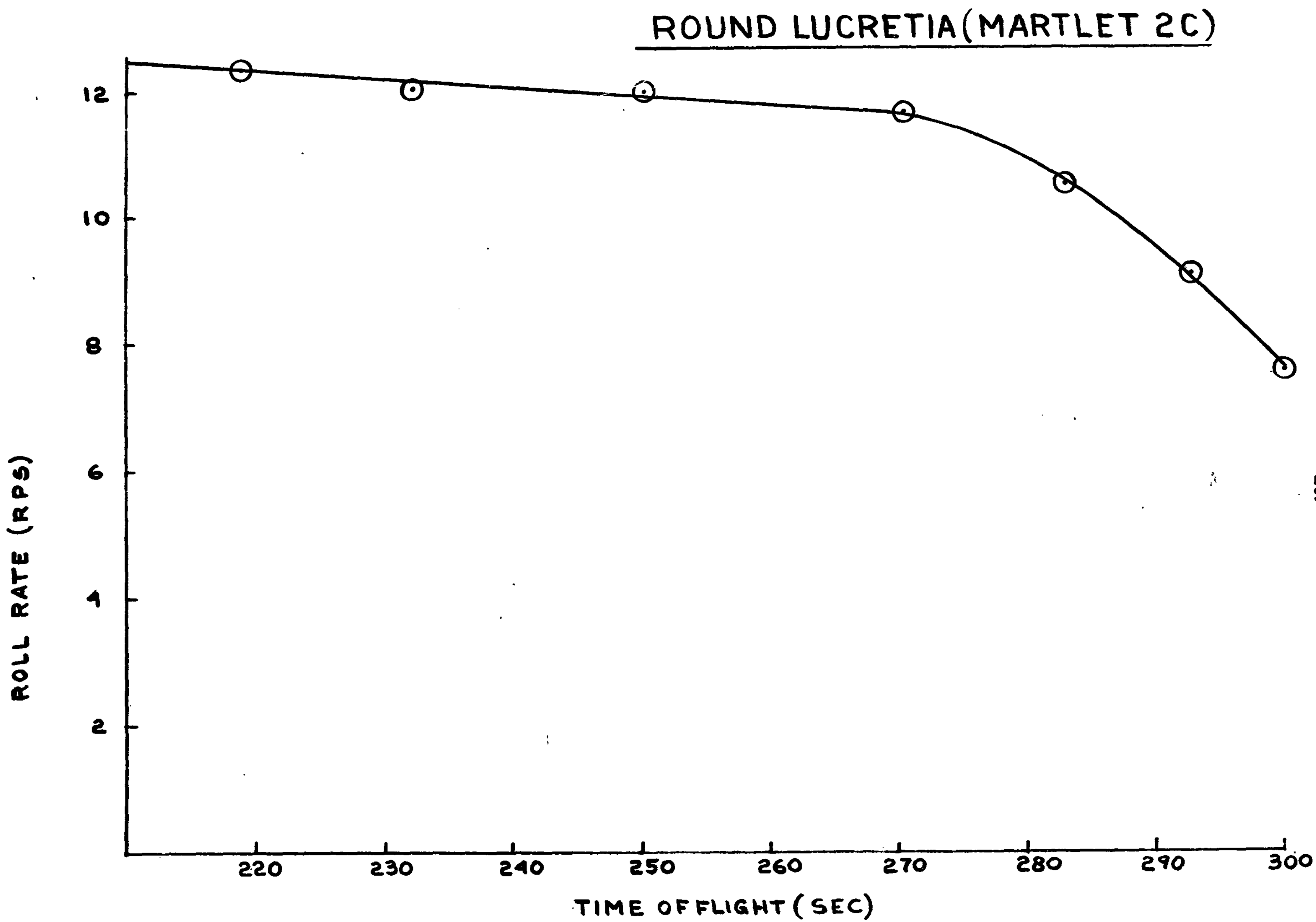


FIG.43 ROLL RATE VS FLIGHT TIME

ROUND LUCRETIA (MARTLET 2C)

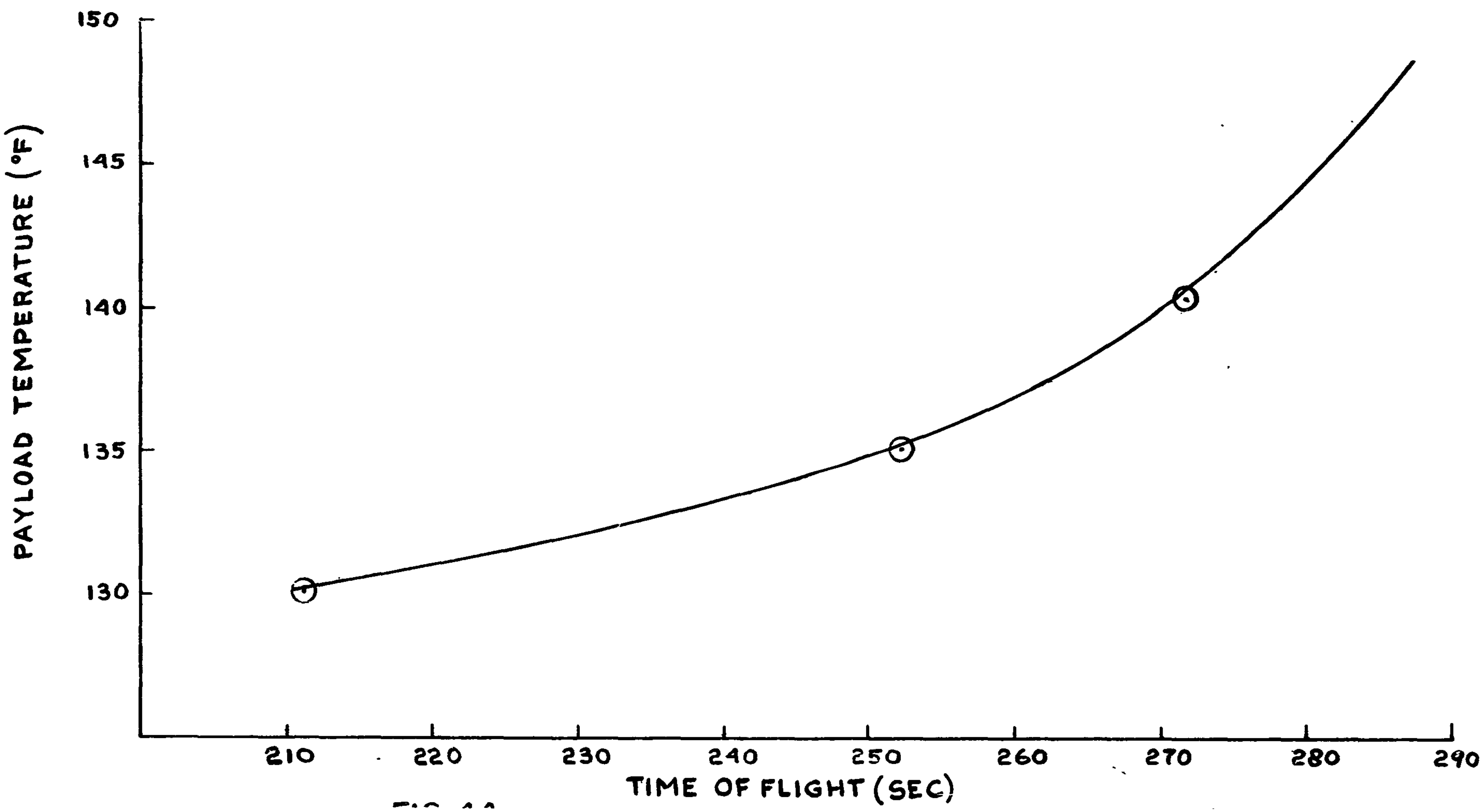


TABLE XV

GROUND CALIBRATION DATA FOR ROUND LUCRETIA

Magnetometer

Normal Magnetic Field (milligauss)	SCO Frequency (Hz)
+600	38,930
500	38,290
400	39,688
300	40,177
200	40,605
100	41,080
0	41,680
-100	42,196
-200	42,692
-300	43,170
-400	43,611
-500	44,030
-600	44,400

Thermistor

Temperature (deg F)	SCO Frequency (Hz)
77	9,760
85	10,000
125	10,500
230	11,000

9.1.2 Round No. 16 - CICERO

Telemetry signals were not received from round CICERO until T + 206 sec and transmission lasted until T + 300 sec. Again, both subcarriers functioned and some data were obtained. A centre frequency shift of about 6 KHz was observed on the magnetometer channel. It is not possible to assess the amount of centre frequency shift on the temperature channel because the zero reference frequency was not measured before launch. An unusually large shift in transmitter frequency of 12.5 MHz was observed, although in part attributable to drifting during the flight.

Despite the substantial centre frequency shift, the magnetometer data have been treated as though ground calibrations were valid. The results for the portion of the flight over which data were received are shown in Fig. 45. Roll rate data were derived from the magnetometer channel and are shown in Fig. 46.

Because of the absence of preflight zero reference data, it is not possible to construct a temperature profile from the temperature channel data. The flight data are shown in Fig. 47 in terms of frequency versus time.

The magnetometer and temperature calibration data are listed in Table XVI.

ROUND CICERO (MARTLET 2C)

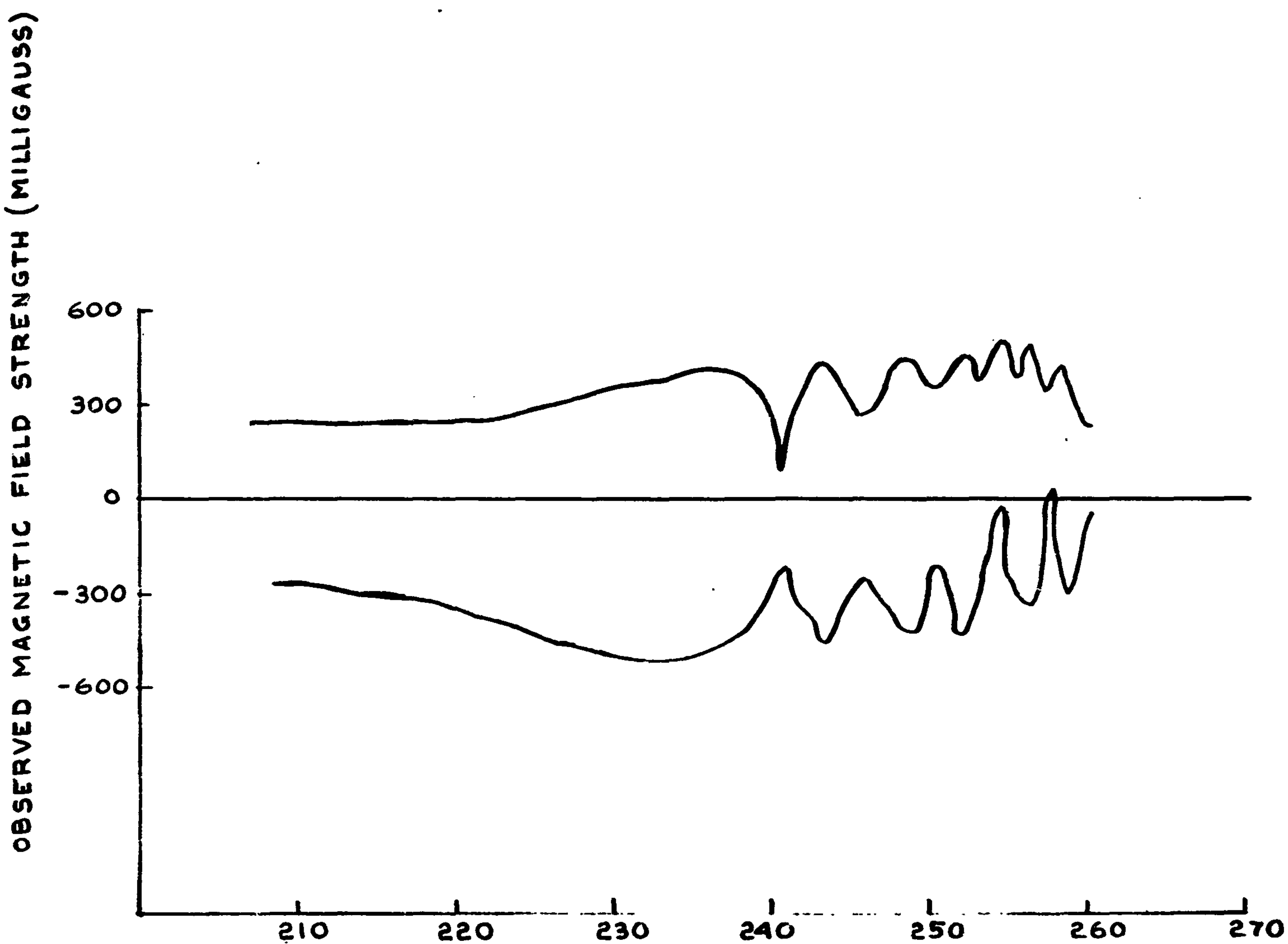


FIG.45 MAGNETIC FIELD STRENGTH VS FLIGHT TIME

ROUND CICERO (MARTLET 2C)

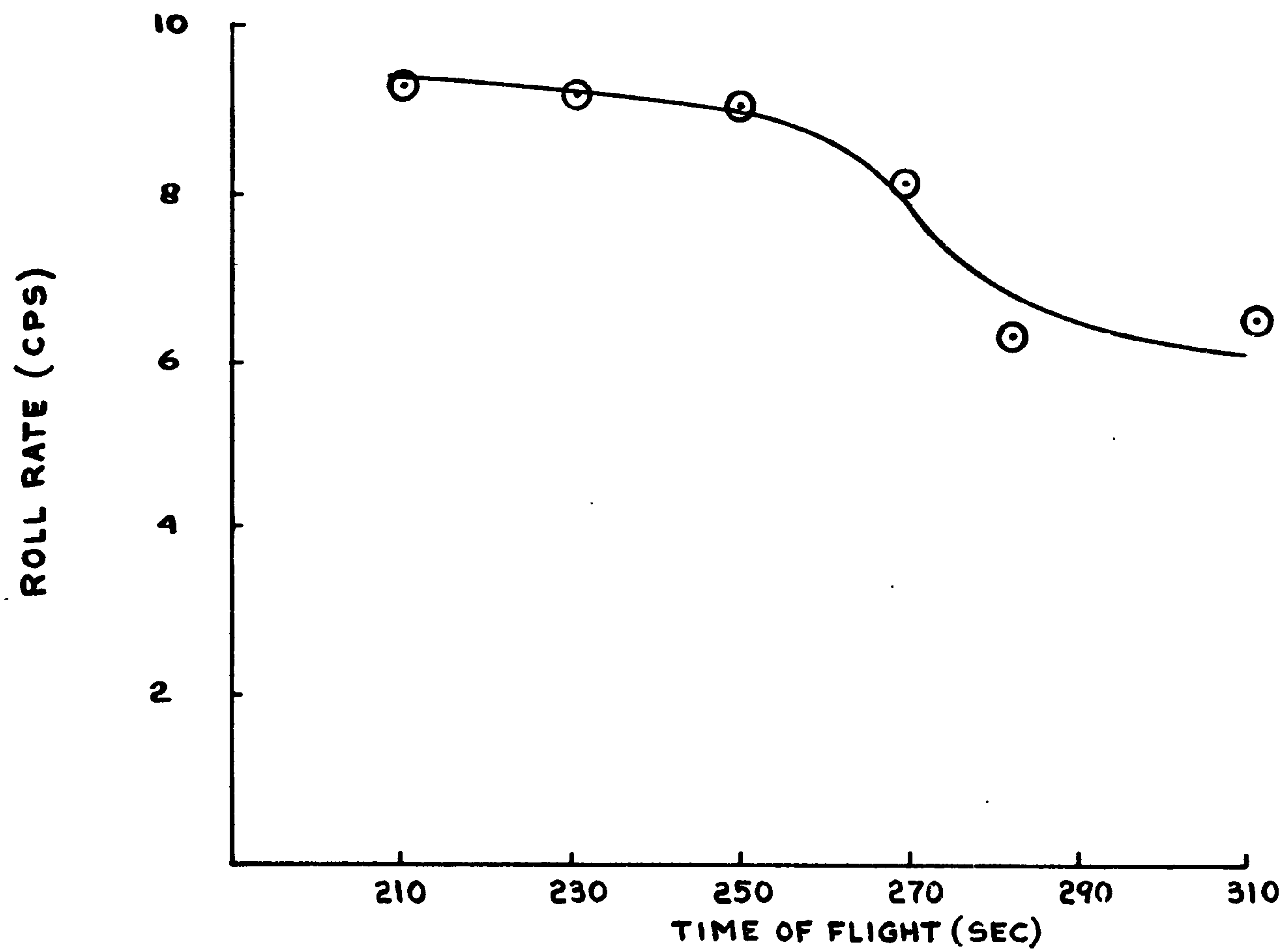


FIG 46 ROLL RATE VS FLIGHT TIME

ROUND CICERO (MARTLET 2C)

TEMPERATURE VCO FREQ.

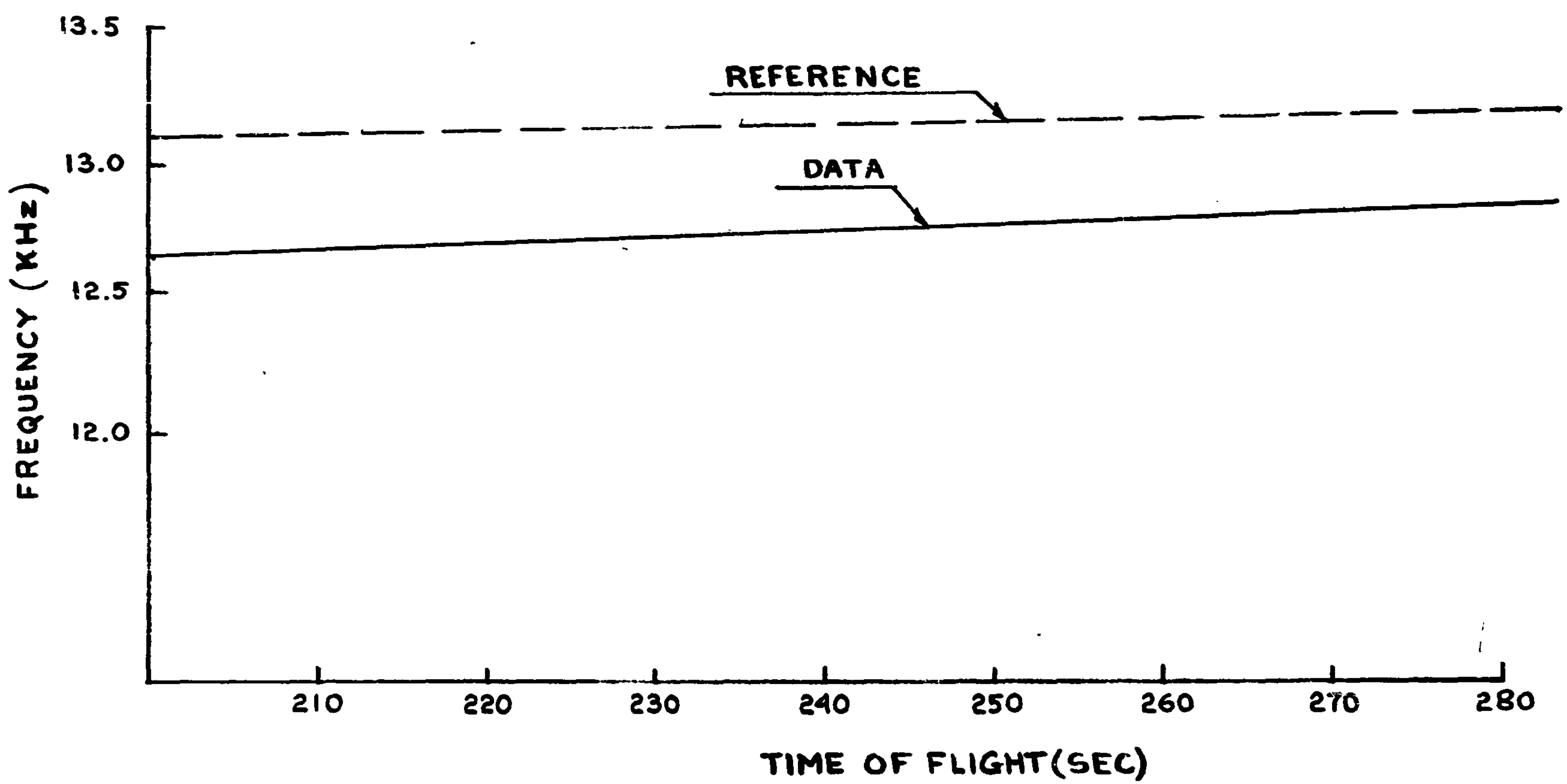


FIG. 47 FREQUENCY VS FLIGHT TIME

TABLE XVI

CALIBRATION DATA FOR ROUND CICERO

Magnetometer

Normal Magnetic Field (milligauss)	SCO Frequency (Hz)
+600	37,981
500	38,369
400	38,802
300	39,267
200	39,765
100	40,302
0	40,850
-100	41,415
-200	41,921
-300	42,406
-400	42,855
-500	43,276
-600	43,648

Thermistor

Temperature (deg F)	SCO Frequency (Hz)
77	10,530
85	10,810
105	11,170
130	11,380
150	11,760

9.1.3 Round No. 17 - DIANA

Intermittent telemetry signals were received from T + 55 to T + 85 sec, the total duration of transmission amounting to only a few seconds during this interval. The transmitter frequency shifted a substantial 16.5 MHz after launch and recorded signal strengths were quite weak. A broken antenna is indicated. The received signals showed the magnetometer and bead thermistor to be functioning during the flight but the data were fragmentary and not worth presenting.

9.1.4 Remarks

In general, the telemetry performance was poor. The three telemeters failed to transmit over most of the flight path. It is tempting to ascribe this failure to the poor antenna pattern associated with the 2C nose-spike antenna and the unfavorable location of ground receiving antennas, but this seems unlikely to be the correct explanation. In one of the three shots, LUCRETIA, the transmitted signals were strong at loss and at reacquisition. When transmission was finally received from CICERO, the received signal was strong and came on abruptly. With a poor antenna pattern, one would expect fading out and fading in of the transmitted signal. Moreover, if the pattern is to blame, one would expect uniform behavior of all shots. DIANA, however, shows transmission during the supposedly "blacked out" part of the trajectory (from say T + 20 to T + 200 sec). Certainly the

antenna design is not optimum for use at Barbados, but the transmission failure in mid-flight must be ascribed to other causes. Ablation effects, transmitter frequency "jump", and aerodynamic heating, or component failure might account for the trouble and should be explored.

The substantial shifts observed in both transmitter and subcarrier oscillator frequencies on launch indicate the need for circuit revisions and greater attention to component selection and preflight testing. Zero reference measurements should be provided in-flight on all subcarrier oscillators. A two-point calibrator would be preferable.

Shots LUCRETIA, CICERO, and DIANA did demonstrate that flux-gate magnetometers could be used in HARP flights. Internal temperatures of the order of 150 deg F have been measured, which shows a need for circuit temperature compensation.

9.2 1750 MHz Telemetry/Langmuir Probe Results

9.2.1 Introduction

This section describes the experimental results obtained from four rounds equipped with the BRL 1750 MHz telemetry system. In one of the rounds (No. 2, Martlet 2A - RUFUS), the telemetry package was parachute-borne and had bead thermistors for ambient temperature measurements. The three other rounds, using the Martlet 2C - Mod. 1 vehicles, were instrumented with aspect magnetometers and Langmuir probe sensors. These rounds were No. 11 - BRUTUS (DC Langmuir probe), and Nos. 4 - IRE and 12 - JANUS (AC Langmuir probes).

9.2.2 Test Objectives

The test objectives were as follows:

1. To conduct field tests of the BRL 1750 MHz telemetry/sensor system in the Martlet 2 projectiles to supplement the previous tests of the telemetry system at Wallops Island in the 5-inch gun projectiles.

2. To conduct the first test of the BRL 1750 MHz modified GMD angle tracking system on Martlet 2 projectiles.

3. To make additional payload-temperature measurements to supplement those previously made.

4. To conduct the first test of the parachute temperature sensor system, and

5. To conduct the first tests of the DC and AC Langmuir probes on the Martlet 2 projectiles.

9.2.3 Instrumentation Flown

The parachute temperature-measurement payload (Fig. 48) consisted of a 1750 MHz FM transmitter (approximately 100 milliwatts); a subcarrier oscillator at 10.5 kilocycles; an 8 x 5 commutator to sample four temperature sensors (bead thermistors) located on the parachute shroud lines, one sensor in the payload, and two calibration voltages; a "sloop" (slot-loop) antenna; a nickel-cadmium battery; and an acceleration switch. The payload was to be ejected from the rear of the projectile by a fuse-initiated powder charge after 120 sec of flight.

The ion and electron density measurement payloads (Fig. 49) consisted of a 1750 MHz FM transmitter, two subcarrier oscillators, an 8 x 5 commutator to sample the Langmuir probes*, a flush resonant cavity antenna, battery pack, and acceleration switch. An aspect magnetometer to measure spin rate and attitude, and sensors to measure on-board temperatures also were carried on each of these rounds.

9.2.4 Test Results

The BRL 1750 MHz telemetry transmitter survived the launch acceleration on all four Martlet 2 rounds fired at Barbados (about 20,000 g for 35 milliseconds), and the signals were received immediately after launch without retuning the receiver (the reliability of the transmitter has now been demonstrated by six successes in six gun firings to date).

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* Developed under contract by GCA Corporation.

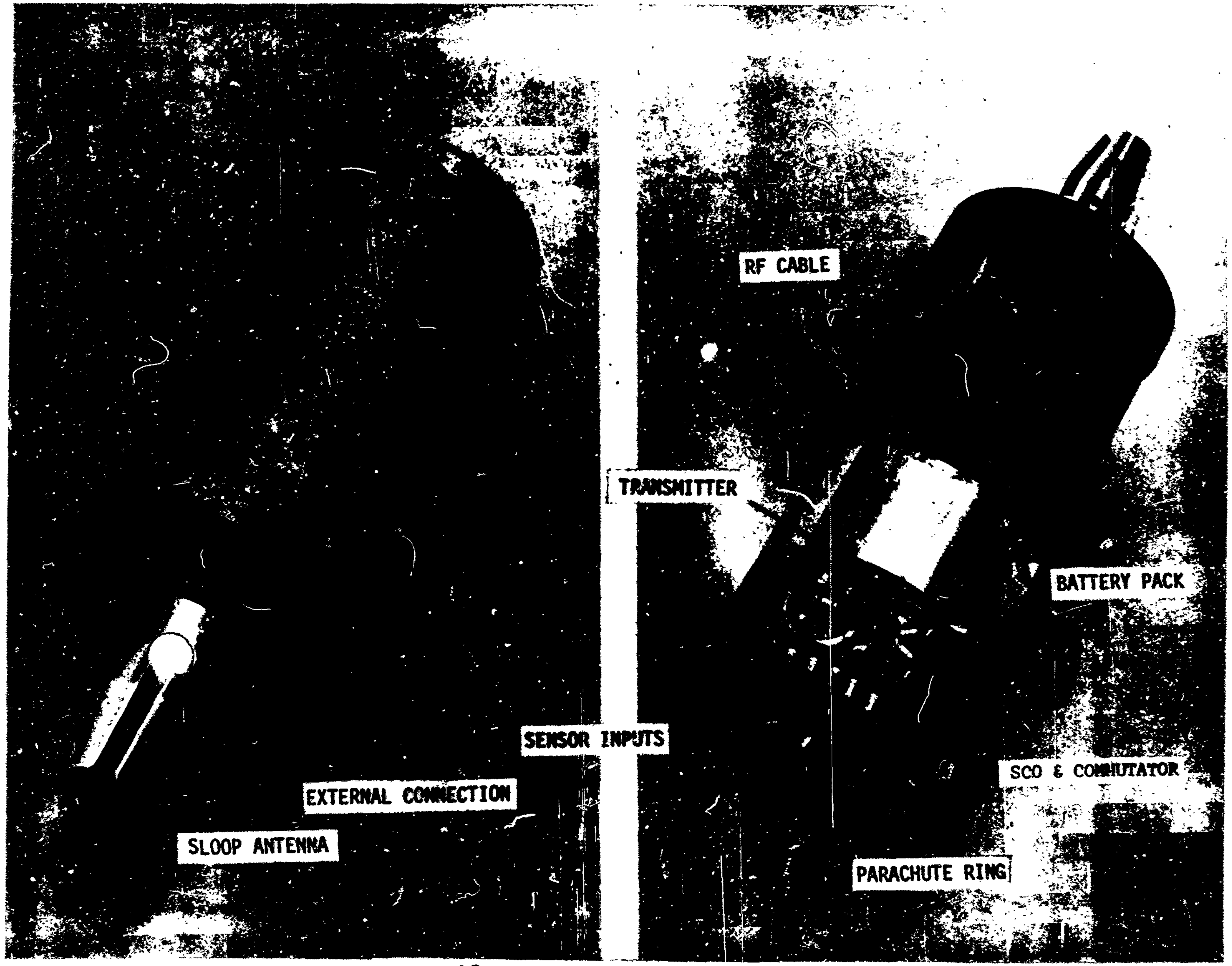


FIGURE 48 EJECTABLE - PARACHUTE PAYLOAD

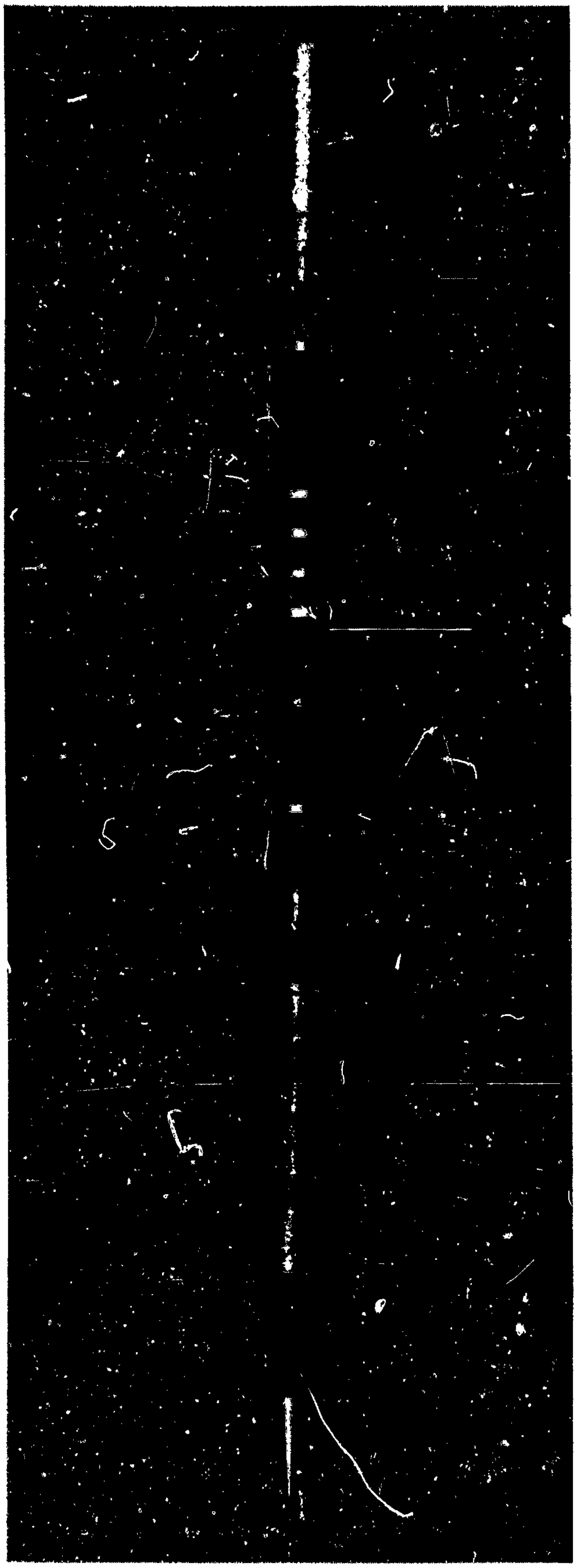


FIG. 49 MARTLET 2C MOD 1
Ion and Electron Density
Measurement Payloads.

The two new types of antennas designed for the Martlet 2 payloads provided strong signals during the portion of the flight when the projectile axis was directed toward the receiving site. Some minima were observed when the projectiles yawed or precessed.

Signals were received from the rounds RUFUS (which did not eject), BRUTUS and IRE for 223, 240 and 233 sec respectively, with some breaks in the received-signal records. A continuous signal was received from the round JANUS, for 210 sec, with no breaks in the record. The signals from all rounds ceased on descent, prior to impact, probably due to cutoff of the transmitter from aerodynamic heating effects.

Angle tracking data were obtained with the modified GMD tracking unit during three of the four Martlet 2 firings. The tracking unit was inoperative during the fourth firing due to a circuit breaker failure. On one round, IRE, which veered off course more than 100 deg after launch because of a damaged fin, the modified GMD tracking unit was the only tracker which succeeded in acquiring and tracking the projectile. The tracking data for the round JANUS are shown in Fig. 50.

On-board temperature data collected near the transmitter units (which were located at the rear of the projectiles in the vicinity of the fins) were obtained from the rounds. These data indicated that the transmitter temperatures had reached 67 to 69 deg C when the transmission ceased. Apparently, the increased current drawn by the heated transistors caused the transmitters to fail.

Good DC Langmuir probe data were received from the round BRUTUS (Fig. 52). The electron densities agree very well with those expected in the D-region of the ionosphere between 65 and 110 kilometers. A collector current of 1.7×10^{-6} amperes was observed at launch which decreased to 4.0×10^{-8} amperes during the first 50 seconds of flight. This phenomenon was probably due to shunting contaminants on the surface of the nose tip collector which evaporated or burned off during flight. The same effect has been observed on rocket flights.

The AC Langmuir probe data from the round IRE were impaired by a failure of the telemetry subcarrier oscillator; however, a backup commutated subcarrier oscillator did provide some AC Langmuir probe data which is being evaluated by the GCA Corporation. No AC Langmuir probe data were obtained from the round JANUS. This result was probably due to a transistor failure.

9.2.5 Problem Areas

Interruptions were observed in the telemetry signals from three rounds, RUFUS, BRUTUS and IRE. These breaks were probably due to abrupt frequency shifts (causes unknown) and antenna pattern nulls. However, the slow frequency drift of the transmitted signals due to aerodynamic heating was easily followed by manual tuning of the telemetry receiver. The latter frequency shifts were only 14 to 44 MHz or 0.8 to 2.5 percent changes.

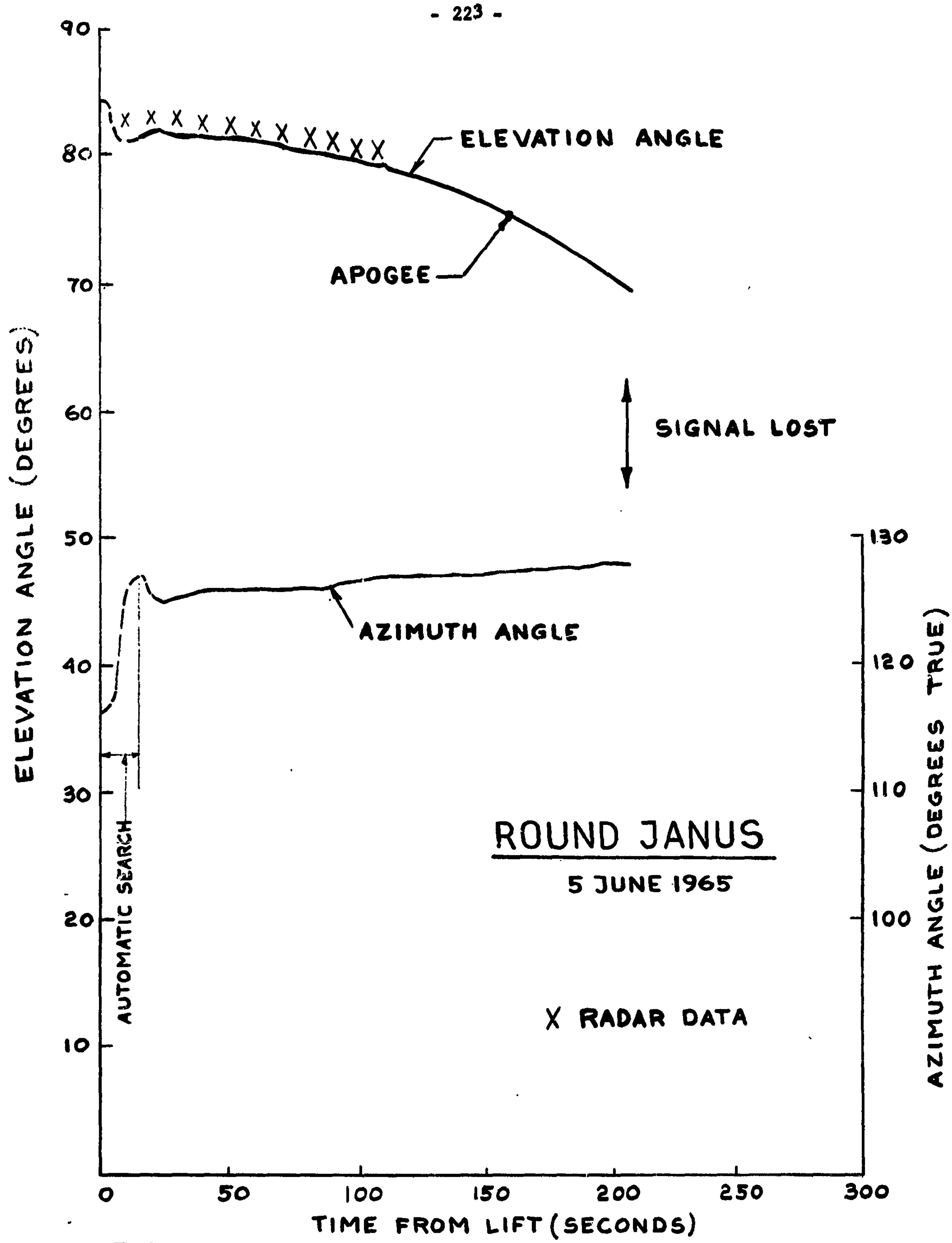


FIG.50 GMD TRACKING DATA FOR ROUND JANUS, AZIMUTH AND ELEVATION ANGLE VS TIME

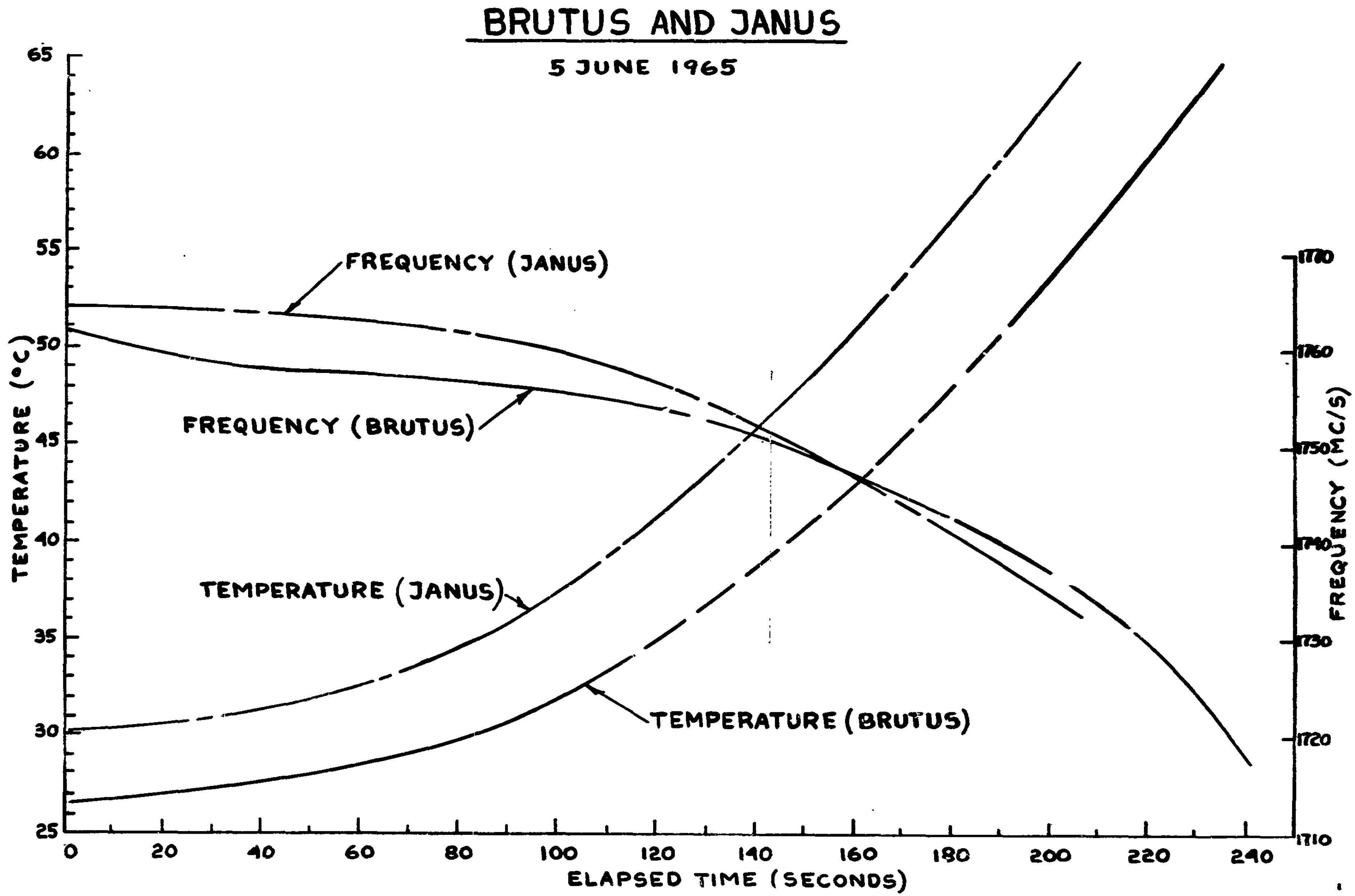
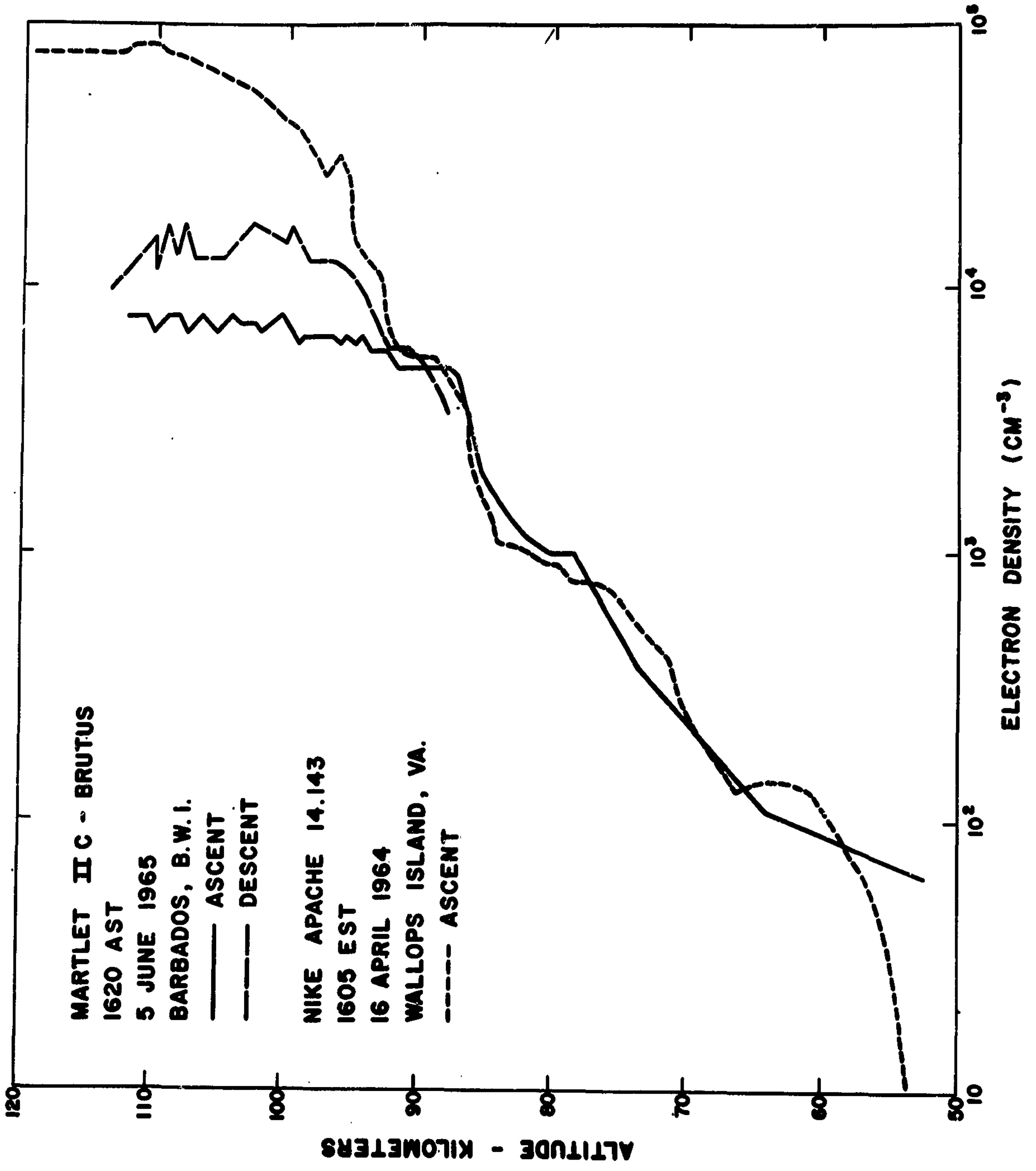


FIG.51 SHOTS BRUTUS AND JANUS, TRANSMITTER FREQUENCY

FIG.52 GUN PROBE MEASUREMENTS OF IONOSPHERIC ELECTRON DENSITY



An indication of fuze and charge activation was obtained at 100 sec of flight on the parachute round, RUFUS, However, the parachute payload was not ejected as was indicated by the constant spin rate of the projectile (measured by the telemetry AGC signal) and a fall rate of the payload which matched that of the projectile. Ejection failure may have resulted from the inability of the fiber-glass plug at the rear of the projectile to strip the holding cap screw.

A preliminary checkout of the AC Langmuir probe on the round IRE, disclosed a failure of one of the transistors, probably due to poisoning by the potting compound. However, a pre-flight test showed that the transistor was working properly. The same self-curing effect had been observed previously in the laboratory.

10.0 SUMMARY AND CONCLUSIONS

The May/June test series had the two principal objectives, as outlined in Chapter 1, of a continuation of vehicle development and reliability tests, and the gathering of scientific data. The results of this test series are summarized in the following by ~~discussing~~ (1) gun performance, (2) vehicle performance, (3) payload performance, and (4) the scientific results obtained from the experiments.

10.1 Gun Performance

The gun ballistic performance with M8M.220 propellant was satisfactory and in agreement with previous results. A Martlet 2C of 186 lb vehicle weight achieved record apogee of 444,000 ft (135 km) with a breech pressure of 48,000 psi, i.e., still well below the capacity of the gun. In one round the gun was evacuated; there was, however, no indication that this had an effect on the muzzle velocity.

10.2 Vehicle Performance

The performance of the Martlet 2 vehicle proved satisfactory. In some of the firings, specifically those with a large charge load, a large azimuth dispersion was observed, caused by a pusher plate and gun barrel problem. Appropriate modifications were made which eliminated the dispersion.

In both Martlet 3B firings, the fins were stripped in the barrel; this, however, could evidently not be attributed to a vehicle structure problem as in later firings in another barrel

and under the same conditions, the configuration emerged undamaged. The fin stripping appeared to be caused by residual rifling showing up in the first twenty feet of travel. Recovered fin parts indicated that failure could have been from this source. Spin has been observed on the vehicles at launch. Future efforts will be directed towards barrel reboring to eliminate the rifling entirely.

10.3 Payload Performance

TMA trails were obtained in all night firings although some of them were of poor quality. This was in part due to bad weather conditions. In a later test series it was also discovered that the TMA piston did not work properly under excessive rebound loads in the TMA payload. This problem was then overcome by using new pistons.

The Lockheed system of fluid support for a grain within a case was flown successfully*. It was clearly demonstrated that the end-burning propellant configuration supported in the motor chamber by fluid could endure high launch acceleration. The epoxy potting support technique was also shown to be satisfactory. Moreover, a radiographic inspection of a recovered motor indicated that no cracking or permanent deformation had taken place during launch.

Tests with the pyrotechnic fuze ejection system were not successful. Ejection failure was observed in all three rounds, although there was an indication of fuze and charge activation in

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* A detailed report will be issued in the future.

the round RUFUS.

The 250 MHz telemetry performance was not satisfactory since the three telemeters failed to transmit over most of the flight path. The 1750 MHz telemetry system, however, performed properly.

The test flights with flux-gate magnetometers demonstrated clearly that the magnetometers survived the high launch accelerations and were able to perform during flight.

10.4 Scientific Results

Synoptic wind measurements were obtained in three nights, resulting in wind shear data during these nights near the 100 km altitude level. Good electron density results were obtained with Langmuir probes, indicating a density distribution in the D-layer as expected.

10.5 Conclusions

In general, the test series met the objectives set, demonstrating that gun launching of rockets with end-burning type grain is feasible, and that flux-gate magnetometers can be used in HARP vehicles. The modified angle-tracking system also proved satisfactory.

In addition, useful scientific information was obtained.

The series showed, however, that the ejection system is not yet operational and requires modification. Furthermore, as a result of the poor performance of the 250 MHz telemetry system, investigations are indicated on ablation effects, transmitter frequency "jump" and aerodynamic heating as well as component failure as possible causes for the unsatisfactory telemetry performance.

REFERENCES

1.	Bull, G.V. and Luckert, H.J.	Report on the March 1965 Test Firing Series, Project HARP, Rep. SRI-H-R-9, July 1965.
2.	Space Instruments Research	a) Photographic Prints of TMA Releases HARP Series, 3-11 June 1965, Vols. #1 and 2, July 1965.
		b) Upper Atmosphere Winds from Gun Launched Vertical Probes, Tech. Report #1, November 1965.

APPENDIX A - RADAR RESULTS

Time	1. APPIUS MPS-19 Altitude	Range	M-33 Altitude	Range	2. RUFUS MPS-19 Altitude	Range	M-33 Altitude	Range
(sec after launch)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
10	44,000	4,250						
15			55,500	6,800				
20	81,000	8,200	82,300	9,200	87,500	8,750	71,900	8,050
30	115,000	12,000			119,000	12,500	111,200	13,600
40	145,200	15,500			147,000	16,000	142,100	17,900
50	172,800	20,000	175,000	19,300	172,500	20,000	169,200	21,700
60	197,000	23,400			194,200	23,000	190,400	24,700
70	218,000	26,600			213,000	27,000		
80	235,000	33,800			228,800	30,500		
90	250,200	36,800			241,000	34,000		
100	262,000	38,500			250,300	39,000		
110	270,700	41,000			256,500	42,200		
120								
	5. MARIUS				6. NERO			
10	49,650	4,500						
13			77,840	5,465				
20	93,000	8,250	94,700	7,105			86,300	7,800
25			99,500	7,560				
30	133,400	12,300	133,300	10,830			121,100	11,750
40	170,300	15,300	173,300	14,680			156,000	17,420
50	204,000	18,000	206,630	17,900			184,300	18,600
60	234,300	20,300	234,900	20,620				
70	261,900	22,200						
80	285,800	26,700						
90	307,200	30,800						
100	324,700	36,800						
110								
120								

APPENDIX A - RADAR RESULTS (Cont'd)

Time	7. ELAGABULUS MPS-19 Altitude	Range	M-33 Altitude	Range	8. FABIUS MPS-19 Altitude	Range	M-33 Altitude	Range
(sec after launch)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
10	52,500	3,750			49,500	3,500		
20	97,500	6,900			92,800	6,500		
30	138,500	10,800			132,000	9,250		
40	176,700	14,000	177,000	13,400	168,000	12,000		
50	211,800	16,800	212,200	16,500	201,300	14,500		
60	243,800	18,750	244,100	19,300	231,000	17,500	234,400	19,70C
70	272,500	20,850			258,000	21,500	259,300	22,00C
80	298,300	22,500			281,800	24,800	282,600	24,20C
85							292,800	25,10C
90								
100								
110								
120								

Time	9. GRACCHUS MPS-19 Altitude	Range	M-33 Altitude	Range	10. SPARTA MPS-19 Altitude	Range	M-33 Altitude	Range
10	50,800	7,200			42,000	5,900		
20	93,800	13,700	93,300	13,900	76,500	11,000	77,300	11,300
30	134,300	20,300	134,100	20,400	108,000	16,300	108,300	16,700
40	171,000	26,400	172,200	26,600	136,000	21,500	136,200	22,000
50	205,300	32,800	206,200	33,100	161,000	27,300	161,600	27,100
60	235,800	37,800	236,100	39,900	183,000	30,500	183,100	31,600
70	264,000	42,300	263,900	45,950	201,800	35,000	202,100	37,600
80	288,300	46,800			217,000	40,500	217,100	43,400
90	310,500	51,800			229,500	44,500	229,700	45,900
100					238,800	47,000		
110								
120								

APPENDIX A - RADAR RESULTS (Cont'd)

Time	11. BRUTUS MPS-19 Altitude	11. BRUTUS MPS-19 Range	11. BRUTUS M-33 Altitude	11. BRUTUS M-33 Range	12. JANUS MPS-19 Altitude	12. JANUS MPS-19 Range	12. JANUS M-33 Altitude	12. JANUS M-33 Range
(sec after launch)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
10	51,200	7,900			51,000	7,350		
20	96,200	15,000	93,500	14,560	95,000	13,950		
21							101,800	14,790
30	137,600	21,900	134,500	21,720	136,500	20,600	135,860	20,430
40	175,500	30,000	175,200	28,900	174,500	27,000	178,800	27,520
50	210,500	36,400	211,600	36,500	208,800	33,800	210,170	33,525
60	242,900	42,000	240,200	41,900	240,300	39,300	240,400	40,860
70	271,900	46,400			268,800	45,000	268,300	45,810
80	297,400	51,500			294,200	50,100		
90					316,500	55,000		
100					336,000	59,300		
110								
120								
	14. LUCRETIA				15. OVID			
10	51,450	8,100			48,000	8,400		
20	96,380	15,500			90,000	15,000		
21							97,490	15,800
25							109,500	18,000
30	137,900	22,800			127,500	22,200	127,900	21,400
40	175,500	29,900			162,300	28,630	162,400	28,720
50	210,800	36,000			194,100	34,500	195,400	34,970
60	243,000	42,000			222,800	39,800	223,100	40,940
70	270,800	52,800	271,800	50,800	248,900	44,500	252,000	46,700
80	296,850	58,500			271,500	48,300		
90	317,100	74,600						
100								
110								
120								

APPENDIX A - RADAR RESULTS (Cont'd)

Time	16. CICERO				17. DIANA			
	MPS-19		M-33		MPS-19		M-3:	
	Altitude	Range	Altitude	Range	Altitude	Range	Altitude	F
(sec after launch)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	
10	48,900	6,450			49,500	7,500		
15			72,900	11,400				
20	91,200	12,900	89,940	12,830	91,800	13,950	91,950	1
25							115,400	1
30	130,200	19,500	131,300	19,200	131,700	21,000	132,300	2
40	165,000	25,500	165,000	26,200	167,900	27,800	168,600	2
50	198,000	30,900	199,340	33,200	201,000	33,900	201,400	3
60	226,800	39,400	232,640	39,300	231,000	39,800	231,300	4
70	253,500	43,500	254,000	45,000	258,000	45,900	257,600	4
80	276,800	47,400	276,500	51,510	281,700	51,000		
90	297,200	51,000			303,000	55,200		
100	314,200	54,300			320,700	60,000		
110								
120								

Time	18. PLINY				19. QUINTUS			
10	54,600	7,200			54,000	4,500		
20	102,000	13,200			102,000	9,300		
30	146,300	19,500			147,000	13,700		
40	107,500	27,300			188,700	18,500		
50	225,000	31,500	225,000	33,000	226,950	22,800	232,300	2
60	260,600	36,000	(approx)		262,800	26,300	263,400	2
67							285,200	2'
70	292,400	43,500			294,600	30,000		
80	321,000	48,000			324,000	33,300		
90					349,800	36,300		
100					373,200	39,000		
110								
120								

APPENDIX A - RADAR RESULTS (Cont'd)

	20. HADRIAN			
	MPS-19		M-33	
Time	Altitude	Range	Altitude	Range
(sec after launch)	(ft)	(ft)	(ft)	(ft)
10	53,900	3,900		
20	101,300	7,500		
30	146,100	11,250		
40	187,500	14,550	189,400	14,600
50	225,300	17,240	226,600	17,800
60	260,900	19,800	261,000	20,800
70	292,800	21,630		
80	321,200	24,800		
90	346,800	29,400		
100	367,200	33,800		
110	386,700	35,900		
120	405,000	39,800		
130	415,500	40,700		